NPRM 00-XX/PNPA 25B-2XX

Paragraphs affected: FAR 25/JAR-25 Sub-Part B
FAR/JAR 25.1419
FAR/JAR Appendix C

PERFORMANCE AND HANDLING QUALITIES IN ICING CONDITIONS

Introduction/Summary[1]

This NPA/NPRM is based on text developed by the Flight Test Harmonization Working Group (FTHWG), a group of European and North American airworthiness authorities' and industry flight specialists, and pilot representatives working to harmonize Subpart B of JAR 25, FAR 25 and Transport Canada's Part 525. As an element of the Harmonization Work Program, the FTHWG reports to the JAA and to the Transport Airplane and Engine Issues Group (TAEIG). The TAEIG, in turn, is empowered by and reports to the Aviation Rulemaking Advisory Committee (ARAC), a standing committee established by the FAA in February 1991 that consists of representatives from aviation associations and industry to provide industry input in the form of information, advice, and recommendations to be considered in the full range of FAA rulemaking activities.

The harmonized requirements and associated guidance material of this NPA supersede the European Joint Aviation Authorities' (JAA) NPA 25F-219, Issue 2, as published for consultation on April 23, 1993. The task for the FTHWG was to review NPA 25F-219 and the comments received following public consultation on the NPA and to recommend new or revised requirements and compliance methods related to airplane performance and handling characteristics in icing conditions.

The FTHWG proposes to amend FAR 25/JAR-25 to revise the requirements related to ice protection systems and introduce requirements to evaluate airplane performance and handling characteristics in the icing conditions of Appendix C to FAR 25/JAR-25. Harmonized advisory material providing guidance on compliance with these requirements has also been developed. Several of the proposed requirements were the subject of considerable debate within the FTHWG, most of them having two positions supported by an almost equal number of member organizations. Consensus was eventually reached on all but one of these requirements – the pass/fail criteria for the zero-g pushover maneuver used to investigate an airplane's susceptibility to ice-contaminated tailplane stall. It was therefore decided to present the majority position in the Draft NPA/NPRM with countering minority positions presented and dispositioned in the preamble. Note that one member organization also submitted two "minority positions" relative to the proposed advisory material clarifying what the "critical" ice accretion is for the various phases of flight and the delay time appropriate for determining an ice accretion that would exist on unprotected and protected surfaces before normal ice protection system operation.

JAA NPA 25F-219 will be withdrawn on adoption of these proposals.

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[1] This section will most likely require slightly different wording for the NPA and NPRM due to format differences that exist in the FAA and JAA systems.

Background

The FAA, JAA and Transport Canada currently have various documents addressing handling and performance in icing conditions. These documents have been amended over the years to add requirements as a result of information acquired from research, and incidents and accidents that have occurred in icing conditions; for the most part each airworthiness authority developed this material independently. Consequently, it was recognized that little material existed addressing satisfactory standards for flight characteristics (i.e. performance and handling qualities) for operation in icing conditions, and what did exist was not standardized among the airworthiness authorities.

The JAA took a major step in developing a comprehensive set of criteria for certificating transport category airplanes for flight in icing conditions with the publication of NPA 25F-219 in the late 1980s; NPA 25F-219 presented Draft Advisory Material Joint (AMJ) 25.1419, "Flight in Icing Conditions - Acceptable Handling Characteristics and Performance Effects." To develop this material, the JAA Flight Study Group established an Icing Sub-Group, comprising Flight and Systems specialists from the European airworthiness authorities and industry. The Icing Sub-Group's initial task was to consider tailplane stall/elevator over-balance and a push-over maneuver to zero "g" was developed to evaluate an airplane's susceptibility to this phenomenon. A further task was to develop policy on airplane performance and handling qualities criteria for flight in icing conditions, which was based on identification of existing practices and a review of the clear air flight test requirements. The intention was to formalize and harmonize the various European practices and this aim was made more urgent by the advent of JAA Joint Certifications.

At this stage the French DGAC prepared Special Conditions for the type certification of turboprop airplanes based on the early work of the Sub-Group, Transport Canada Advisory Material, and its own experience. With modifications to accommodate wider application, these Special Conditions subsequently formed the basis for the further work of the Sub-Group, resulting in the development of NPA 25F-219.

NPA 25F-219 Issue 2 was published for subscribers' comments on 23 April 1993. During its development, the NPA had been used in many certifications and it was also formally adopted for certification as JAA Interim Policy INT/POL/25/10, pending formal acceptance for JAR 25. This has now been re-classified as Temporary Guidance Material TGM/25/02, following the introduction by the JAA of this latter category.

Concurrently, the FAA was proposing revisions to Advisory Circular (AC) 25-7 "Flight Test Guide for Certification of Transport Category Airplanes" which included new material addressing flight characteristics in icing conditions. Similar to the JAA's effort with NPA 25F-219, this was the FAA's first attempt to publish guidance dedicated to the evaluation of transport category airplane performance and handling characteristics in icing conditions. Following discussion of NPA 25F-219 and the proposed AC 25-7 material in the JAA Flight Studies Group (FSG), the subject was raised in 1994 as a FAA/JAA harmonization item and the Flight Test Harmonization Working Group was tasked with reviewing NPA 25F-219 and the comments received during the public consultation. The FTHWG considered whether this issue should be addressed by requirements or solely by advisory material. The consensus was that new requirements in Subpart B were required.

There was also debate in the working group as to whether full compliance with Subpart B was required for flight in icing conditions. The final agreement was to require compliance with selected requirements. Hence, the FTHWG took a different approach to that in the NPA: where NPA 25F-219 Issue 2 proposed Advisory Material to 25.1419, this NPA/NPRM proposes rule changes to Subpart B to identify specific performance and handling qualities requirements which must be met, in full or in part, in icing conditions. The remaining flight requirements are considered to be not applicable for flight in icing conditions.

The primary impetus for developing the proposed Subpart B regulations rather than advisory material came from U.S. legal requirements imposed on the FAA by the Administrative Procedures Act. The path originally taken by the FTHWG would have added a paragraph to FAR/JAR 25.21 (Proof of compliance) specifying the Subpart B regulations that had to be complied with and stating the airplane must be able to operate safely in the icing conditions of Appendix C for all other aspects of airplane performance and handling characteristics; advisory material would have interpreted what was meant by "to operate safely" for the non-Subpart B aspects of flight. Under the Administrative Procedures Act, the requirement to show an airplane can "safely operate" would be defined as an "interpretive" rule that would not have the force of law, thus being subject to challenge. The general guideline provided to the FTHWG was that a regulation must establish a requirement or standard that is sufficiently clear to those required to comply with it so that they have a reasonable understanding of what is expected of them without having to resort to material not published in the rule; the regulation must be able to stand on its own. Similarly, the FTHWG was provided guidelines for developing advisory material; it may not impose or lessen a burden on anyone, nor may it have a mandatory effect. Consequently, the FTHWG restructured the material to incorporate what was originally proposed as interpretive advisory material into Subpart B regulations. The proposed regulations amend many existing regulations to include specific criteria related to certification for flight in icing conditions.

The Subpart B requirements for icing conditions were developed with the intent of making certification for flight in icing mandatory by removing the existing conditional statements that preface both FAR and JAR 25.1419. (For reference, FAR 25.1419 requires the airplane be able to safely operate in the icing conditions of Appendix C if an ice protection system is installed while JAR-25.1419 ties the same requirement to the applicant's desire to have the airplane certificated for flight in icing conditions.) The FTHWG's first approach was to revise FAR and JAR 25.1419 to make certification for flight in icing mandatory thus avoiding conflict with the mandatory nature of the proposed Subpart B icing requirements. This approach was later abandoned for several reasons, the final proposal being for the FAA to adopt the wording of JAR-25.1419, which relates compliance with the icing regulatory requirements to an applicant's desire to certificate the airplane for flight in icing conditions. A detailed description of the FAR/JAR 25.1419 issues is provided in the following "Discussion of Proposals" section.

In developing the following proposals, the FTHWG retained the two basic premises the JAA employed when preparing NPA 25F-219: 1) The probability of a transport category airplane operating in icing conditions is <u>one</u>, and 2) All transport category airplanes must show compliance with the same requirements for flight in icing conditions. Similarly, the FTHWG proposals also retain the 1g stall basis for stall speed determination and operating speed factors. The harmonized 1g stall regulatory changes were published for public comments in JAA NPA 25B-215 and FAA NPRM 95-17. The comments received have been reviewed and the final version of these rules were published as Amendment 25-xx on mmddyy and as part of Change 15 to JAR-25 on mmddyy.

The specific requirements that are proposed for certification for flight in icing conditions were determined by a comprehensive review of FAR/JAR 25 Subpart B requirements taking into consideration what aspects were considered most important to ensure safe flight in icing conditions. A second part of this development process was a review of what type and amount of flight testing had been accomplished in previous certifications for the full range of transport category airplanes (i.e., low to high gross weights, straight wing and swept wing, pneumatic de-ice and thermal anti-ice systems, and turbopropeller and turbojet propulsion). This broad review of existing icing certification data was aimed at identifying: 1) any design-specific trends in test requirements, and 2) any safety-related shortcomings that should be addressed by this rulemaking activity.

This review resulted in the concept behind the following proposals being that, whilst degradation in performance in icing conditions may be allowable to a point, in general terms there can be no degradation in handling qualities below the minimum required by Subpart B. There are a few exceptions to this and they are detailed in the following proposals.

Discussion of the Proposals

The FTHWG proposes to harmonize on the introductory wording of existing JAR 25.1419, which relates the need to demonstrate the ability of an airplane to safely operate in the icing conditions of Appendix C to the applicant's desire to have the airplane certificated for flight in icing conditions. The FTHWG also proposes to define a set of FAR/JAR Subpart B airplane performance and handling characteristics standards that must be met by transport category airplanes with the ice accretion appropriate to the phase of flight being investigated; compliance with these requirements, to be specified in FAR/JAR 25.21, "Compliance," will demonstrate the ability of an airplane to safely operate in the icing conditions of Appendix C. In addition, the FTHWG proposes to amend Appendix C of FAR/JAR 25 to define the ice shapes appropriate to each phase of flight.

As a preface to the following discussions of the individual regulatory proposals, it is worthwhile to understand the underlying philosophy that was employed in the development of the criteria the FTHWG considers necessary to show a transport category airplane can be safely operated in icing conditions. The regulatory requirements that follow were primarily determined by a paragraph by paragraph review of the existing FAR/JAR 25 subpart B regulations with consideration given to those aspects deemed critical enough that they should be re-investigated with ice accretions on the airplane. This determination was based on the aforementioned review of incidents and accidents attributed to ice accretion and engineering judgment of what flight aspects are critical for all airplanes.

The review of incidents and accidents revealed that though icing-related performance shortfalls had been the cause of several incidents, due to the negative effects on maximum lift and drag that are inherent with ice accretion, the icing-related accidents resulted from a loss of control that could be attributed to degraded handling characteristics due to ice accretion. Consequently, ice accretions. Where it was recognized that special circumstances existed for icing conditions that would make a particular handling characteristics regulation not completely appropriate, alternate criteria were developed for icing conditions.

With regard to performance, the FTHWG proposal adopts a modified version of the concept utilized by the JAA that permits some tolerance on performance (for the airplane without ice) before requiring that performance be recomputed specifically for operation in icing conditions. JAA Draft AMJ 25.1419 retained the performance threshold criteria introduced by the French DGAC in Special Condition B-(6) for certification of the ATR-72 whereby the need to recalculate performance for a given phase of flight is predicated on the increase in the 1g stall speed due to ice accretion for the associated airplane configuration. That criteria requires the performance to be recalculated for operation in icing conditions, using the 1g stall speed determined with ice, if the 1g stall speed increases by more than the greater of five knots or five percent of the 1g stall speed for the airplane without ice. Since performance degradation was not implicated as a causal factor in any of the icing-related accidents, and since it is accepted that transport category airplanes have used operating speeds in icing conditions that have been determined for the airplane without ice accretion, the FTHWG proposal acknowledges the fact that the FAR/JAR 25 operating speed factors are adequate to permit some amount of tolerance for the negative effects of ice accretion; in particular, the increase in stall speed with ice that reduces the operating speed margin. The FTHWG proposal, however, introduces a smaller stall speed tolerance value than the 5 kts/5%$V_{S\,1\text{-}G}$ criteria of Draft AMJ 25.1419 and also introduces a similar tolerance to the relevant "operating" speed for all phases of flight beyond the FAR/JAR 25 takeoff path; these tolerances will be further discussed in the material associated with each proposed regulation.

The FTHWG considers this performance tolerance approach to be acceptable not only on the basis of service history, but also by introducing certain safeguards into the proposed regulations for the airplane with ice accretions. Operating speeds for icing conditions may also have to be increased in order to show compliance with the maneuver capability requirements of FAR/JAR 25.143 that were introduced by the 1g stall rule.

The following proposals make reference to the "ice accretion" to be used in showing compliance. These ice accretions are defined in a new subsection of Appendix C. It should also be noted that the FTHWG discarded the term "ice shape" in favor of "ice accretion," a term that better describes the formation process and includes the physical characteristics of the ice such as texture and surface roughness particle height in addition to the shape. In adopting this terminology, the FTHWG recognizes that the widely used descriptor "ice accumulations" would have served the same purpose.

<u>FAR/JAR 25.21</u> – Paragraph (g) has been added to specify the requirements that must be met in icing conditions if certification for flight in icing is desired. As noted in the general discussion of the proposals, a review of icing-related incidents and accidents revealed loss of control to be the greatest threat to safety of flight in icing conditions. Consequently, the FTHWG identified the subpart B requirements that could prevent loss of control from occurring if complied with for icing conditions. The result was that with the few exceptions listed in paragraph (g)(1), compliance with most of subpart B was deemed relevant to ensuring safe flight in icing conditions. The regulations that are exempted by paragraph (g)(1) were determined to be beyond what was necessary to determine an airplane's ability to be safely operated in icing conditions.

FAR/JAR 25.21(g)(1) - The objective of the proposed requirements of paragraph (g)(1) is to have essentially no degradation in handling qualities when operating in icing conditions (or after operating in icing conditions with residual ice remaining) with the ice protection systems operating normally. FAR/JAR 25.21(g)(1) also requires compliance with the bulk of the subpart B performance requirements, though as noted in the introductory discussion some tolerance is permitted with regard to showing compliance with the requirements for non-icing conditions; these tolerances are stated in the individual performance regulations. Furthermore, the icing conditions in which compliance must be shown with the proposed requirements are defined as those of FAR/JAR 25, Appendix C. Discussions were held relative to incorporating material related to testing in Supercooled Large Droplet (SLD) icing environments; it was generally felt that such action would be premature since another HWG was tasked with reviewing available data and redefining, if necessary, the icing atmosphere for aircraft certification. An important element of paragraph (g)(1) is the closing text that defines the operation of the airplane to be in accordance with Airplane Flight Manual (AFM) operating limitations and operating procedures, which apart from prescribing the operating conditions, also provides an avenue to include limitations and operating procedures that are specific to operating in icing conditions in the AFM.

FAR/JAR 25.21(g)(2) – Paragraph (g)(2) is proposed to ensure that airplanes will have adequate handling characteristics in the period between the airplane entering icing conditions and the ice protection system performing its intended function. During this period, ice will accrete on both the unprotected and normally protected surfaces; this ice accretion may have a detrimental effect on airplane handling characteristics due to its insidious nature and expanse of coverage. A definition of such an ice accretion is proposed to be added to Part 2 of FAR/JAR 25, Appendix C. The proposed advisory material provides guidance for further defining this ice accretion based on the means of detection.

FAR/JAR 25.21(g)(3) – Paragraph (g)(3) is proposed to prevent the use of different load, weight, and center of gravity limits for flight in icing. The basis of these requirements is that operation in icing conditions should be essentially transparent to the flightcrew in that no icing-specific methods of operation (other than activating ice protection systems) should be required. This philosophy is also based on human factors issues with regard to reducing operational complexity and flightcrew workload.

FAR/JAR 25.21 Proof of compliance

(g) If certification for flight in icing conditions is desired, the following requirements apply:

(1) Unless otherwise prescribed, each requirement of this Subpart, except FAR/JAR 25.121(a), 25.123(c), 25.143(b)(1) and (2), 25.149, 25.201(c)(2), 25.207(c) and (d), 25.239 and 25.251(b) through (e), must be met for flight in icing conditions with the ice accretions defined in Appendix C during normal operation of the airplane in accordance with the operating limitations and operating procedures established by the applicant and contained in the Airplane Flight Manual.

(2) The airplane must meet the requirements of FAR/JAR 25.143(j) and 25.207(h) with the ice accretion prior to normal operation of the ice protection system specified in Appendix C, Part 2(c).

(3) No changes in the load distribution limits of FAR/JAR 25.23, the weight limits of FAR/JAR 25.25 (except where limited by performance requirements of this Subpart), and the center of gravity limits of FAR/JAR 25.27, from those for non-icing conditions, are allowed for flight in icing conditions or with ice accretion.

FAR/JAR 25.103 Stalling Speed – The assumed stall speed basis for the proposed flight in icing requirements is the 1g stall criteria as published for public comment in NPRM 95-17/NPA 25B-215 and subsequently modified during the harmonized disposition of comments received (Note: Publication of the final 1g stall rule is anticipated to occur in late 1999.) The proposed requirements for icing conditions require stall speed to be determined with ice for each airplane configuration; this is conveyed by the revision to FAR/JAR 25.103(b)(3), which adds ice accretion as a configuration variable related to the performance standard for which it will be used. The determination of stall speeds with ice accretions is necessary to quantify any increase relative to stall speeds for non-icing conditions in each flap/gear configuration. This change in stall speed due to ice accretion is then compared with the allowable stall and operating speed tolerances in later subpart B performance standards to determine whether or not the AFM performance for a particular flight phase needs to be recalculated for icing conditions.

FAR/JAR 25.103 Stalling Speed

(a) The reference stall speed V_{SR} is a calibrated airspeed defined by the applicant. V_{SR} may not be less than a 1-g stall speed. V_{SR} is expressed as:

$$V_{SR} \geq V_{CLMAX}/\sqrt{(n_{zw})}$$

where -

V_{CLMAX} = Calibrated airspeed obtained when the load factor-corrected lift coefficient $(n_{ZW}W/(qS))$ is first a maximum during the maneuver prescribed in sub-paragraph (c) of this paragraph. In addition, when the maneuver is limited by a device that abruptly pushes the nose down at a selected angle of attack (e.g. a stick pusher), V_{CLMAX} may not be less than the speed existing at the instant the device operates;

n_{ZW} = Load factor normal to the flight path at V_{CLMAX};

W = Airplane gross weight;

S = Aerodynamic reference wing area; and

q = Dynamic pressure.

(b) V_{CLMAX} is determined with:

(1) Engines idling, or, if that resultant thrust causes an appreciable decrease in stall speed, not more than zero thrust at the stall speed;
(2) Propeller pitch controls (if applicable) in the take-off position;
(3) The airplane in other respects (such as flaps, landing gear **and ice accretions)** in the condition existing in the test or performance standard in which V_{SR} is being used;
(4) The weight used when V_{SR} is being used as a factor to determine compliance with a required performance standard;
(5) The center of gravity position that results in the highest value of reference stall speed; and
(6) The airplane trimmed for straight flight at a speed selected by the applicant, but not less than 1.13 V_{SR} and not greater than 1.3 V_{SR}.

(c) Starting from the stabilized trim condition, apply the longitudinal control to decelerate the airplane so that the speed reduction does not exceed one knot per second.

(d) In addition to the requirements of sub-paragraph (a) of this paragraph, when a device that abruptly pushes the nose down at a selected angle of attack (e.g. a stick pusher) is installed, the reference stall speed, V_{SR}, may not be less than 2 knots or 2%, whichever is greater, above the speed at which the device operates.

FAR/JAR 25.105 Takeoff – FAR/JAR 25.105(a) was amended (and restructured accordingly) to require takeoff performance to be considered for flight in the icing conditions of FAR/JAR 25, Appendix C. In conjunction with the changes to paragraph (a), Appendix C was also amended to define an icing atmosphere appropriate for takeoff conditions.

The proposed changes to paragraph (a) specify the conditions under which takeoff performance must be determined for icing conditions and the ice accretion to be used. As noted in the associated advisory material, the critical surfaces of the airplane are assumed to be clear of ice and snow at the beginning of the takeoff as required by existing operating rules (Ref.: FAR 91.527(a), 121.629(b) and (c), and JAR-Ops 1-345). The proposed requirements assume ice accretion begins at liftoff, which is consistent with operating rules that prohibit flight crews from conducting takeoffs in airplanes with frost, snow or ice adhering to certain airplane surfaces or when the takeoff would not be in compliance with an approved ground de-icing/anti-icing program.

The JAA predecessor to this NPA/NPRM, Draft AMJ 25.1419, which has been applied to numerous certification projects, acknowledged the fact that transport category airplane service history showed some tolerance with regard to the effects of ice on airplane performance. Draft AMJ 25.1419 permitted the stall speed to increase by the greater of 5 knots or 5% of the 1g stall speed (V_{SR}) before takeoff path performance had to be recalculated using the stall speeds determined for the airplane with ice accretions. Several commenters expressed concern with the size of this allowable increase in stall speed, noting the considerable reductions in maneuver capability and stall margin, particularly for the takeoff climb with landing gear retracted (commonly referred to "second segment climb"). This NPA/NPRM retains the tolerance philosophy of Draft AMJ 25.1419 but introduces a smaller and more operationally viable stall speed tolerance. Takeoff path performance must be determined specifically for icing conditions if the uncontaminated 1g stall speed increases by the greater of 3 knots or 3%V_{SR} with the "Takeoff ice" accretion defined in Part 2 of Appendix C (as proposed to be added by this NPA/NPRM).

In addition to the stall speed increase, which allowed a reduction in the margin between stall and the operating speeds for the non-contaminated airplane, Draft AMJ 25.1419 also placed a limit on the increase in drag due to ice accretion before takeoff performance had to be recomputed specifically for operation in icing conditions; Draft AMJ 25.1419 established that limit as a 5% increase in drag. Since climb performance is expressed in terms of a gradient for a given weight, altitude, and temperature (WAT), and since the gradient for a given WAT condition is a function of thrust, lift, and drag, all of which are dependent on airspeed, the FTHWG determined that it would be more appropriate to express the acceptable tolerance of climb performance in terms of climb gradient reduction due to ice rather than just the effect of ice on the drag component alone. The AFM takeoff climb performance is presented in terms of "net" climb gradient, which is computed as the actual climb gradient reduced by specific values prescribed in FAR/JAR 25.115(b). Since operational takeoff performance determinations base obstacle clearance on the "net" takeoff flight path, the actual takeoff flight path will have increasing obstacle clearance as the distance from the starting point of the takeoff flight path increases. Airworthiness authorities have, on occasion, permitted applicants to use up to half of this gradient reduction to account for variables that affect performance. The FTHWG determined that half of the takeoff climb gradient reduction would be an appropriate tolerance on takeoff performance with ice. If the effect of ice exceeds one-half this gradient reduction, the takeoff flight path performance must be recomputed specifically for icing.

Though the "Takeoff ice" accretion is defined as the most critical ice accretion from liftoff to 400 feet above the takeoff surface, it is considered to be a representative performance parameter for the entire takeoff path (which ends at 1,500 feet above the takeoff surface) based on the fact that the landing gear retracted takeoff climb, which comprises the majority of the climb segment for "Takeoff ice" accretion, is generally the most limiting case in the takeoff path. Similarly, the one-half of the takeoff flight path reduction tolerance is related to FAR/JAR 25.121(b), which prescribes the configuration and conditions for the landing gear retracted takeoff climb (second segment), thus again using the limiting takeoff climb case to cover the entire takeoff flight path. An added conservatism inherent to the takeoff path performance arises from the requirement of FAR/JAR 25.111(d)(3) for that performance to be determined without ground effect.

FAR/JAR 25.105 Takeoff

(a) The takeoff speeds described in FAR/JAR 25.107, the accelerate-stop distance described in FAR/JAR 25.109, the takeoff path described in FAR/JAR 25.111, the takeoff distance and takeoff run described in FAR/JAR 25.113, **and the net takeoff flight path described in FAR/JAR 25.115**, must be determined in the selected configuration for takeoff at each weight, altitude, and ambient temperature within the operational limits selected by the applicant—

(1) In non-icing conditions ; and

(2) In icing conditions, if in the configuration of FAR/JAR 25.121(b) with the "Take-off ice" accretion defined in Appendix C:

(i) The stall speed at maximum takeoff weight is increased by more than the greater of 3 knots CAS or 3% V_{SR}; or

(ii) The degradation of the gradient of climb determined in accordance with FAR/JAR 25.121(b) is greater than one-half of the applicable actual-to-net takeoff flight path gradient reduction defined in FAR/JAR 25.115(b).

(b) No takeoff made to determine the data required by this section may require exceptional piloting skill or alertness.

(c) The takeoff data must be based on—

(1) In the case of land planes and amphibians:

(i) Smooth, dry and wet, hard-surfaced runways; and

(ii) At the option of the applicant, grooved or porous friction course wet, hard-surfaced runways.

(2) Smooth water, in the case of seaplanes and amphibians; and

(3) Smooth, dry snow, in the case of skiplanes.

(d) The takeoff data must include, within the established operational limits of the airplane, the following operational correction factors:

(1) Not more than 50 percent of nominal wind components along the takeoff path opposite to the direction of takeoff, and not less than 150 percent of nominal wind components along the takeoff path in the direction of takeoff.

(2) Effective runway gradients.

<u>FAR/JAR 25.107 Takeoff speeds</u> – FAR/JAR 25.107(g) is added to note that the minimum control and minimum unstick speeds, determined as limits on takeoff speeds for the airplane without ice, may be used as limits for determining takeoff speeds for the airplane with ice accretions.

The minimum unstick speed (V_{MU}) is defined in FAR/JAR 25.107(d) as the ". . .airspeed at and above which the airplane can safely lift off the ground and continue the takeoff" and is used as a limitation on the lift-off speed, which in turn effects all other takeoff speeds. Since the FTHWG determined that it is reasonable to assume that ice accretion does not begin until lift-off, the use of the non-icing conditions V_{MU} is justified for use in determining takeoff speeds for icing conditions.

The ground minimum control speed (V_{MCG}) is applied as a minimum limit to the engine failure speed (V_{EF}) in FAR/JAR 25.107(a)(1), which in turn determines the speed V_1 (at which the pilot is either continuing the takeoff or is initiating the first action to abort the takeoff) to ensure adequate directional control for the continued takeoff case should the critical engine fail during the groundborne acceleration run. As with V_{MU}, this occurs prior to lift-off where ice accretion is assumed to begin thus justifying the use of the V_{MCG} determined in non-icing conditions for determining takeoff speeds for icing conditions.

The air minimum control speed (commonly referred to as V_{MCA}) is defined in FAR/JAR 25.149(b) as the airspeed at which it is possible to maintain control of the airplane, with no more than 5 degrees of bank, when the critical engine is suddenly made inoperative. Multiples of V_{MCA} are used in FAR/JAR 25.107 to define minimum limits for the rotation speed (V_R) and the takeoff safety speed (V_2). Again, since V_R occurs before lift-off, where ice accretion is assumed to begin, the use of the V_{MCA} determined for non-icing conditions is considered appropriate for determining limits on V_R.

The case for V_2 is different - in the event of an engine failure, the airborne portion of the takeoff path from 35 feet to 400 feet above the takeoff surface will be flown at V_2. It should be noted that V_2 is a function of several variables, including thrust-to-weight ratio and minimum limits on other takeoff speeds. FAR/JAR 25.111(c)(4) limits airplane configuration changes during this segment to landing gear retraction and propeller feathering. JAR 25 further limits this to automatic propeller feathering and the FAA applies the same limitation through advisory material contained in AC 25.7A. The impact of this limitation is that ice protection systems are typically not activated until the airplane is more than 400 feet above the takeoff surface, sometimes considerably higher if close-in obstacle clearance is a concern. Another concern for the use of the V_{MCA} determined for non-icing conditions is that many airplanes do not have any ice protection on the vertical stabilizer, a situation that could lead to reduced directional control due to ice accretion in the takeoff path that in turn could increase the air minimum control speed. To alleviate these concerns, the FTHWG proposes to amend FAR/JAR 25.143 with a requirement to show that the airplane is safely controllable and maneuverable at the minimum V_2 for takeoff with the critical engine inoperative and with the critical ice accretion appropriate to the phase of flight as defined in proposed additions to Appendix C.

FAR/JAR 25.107 Takeoff speeds

(a) V_1 must be established in relation to V_{EF} as follows:
- (1) V_{EF} is the calibrated airspeed at which the critical engine is assumed to fail. V_{EF} must be selected by the applicant, but may not be less than V_{MCG} determined under FAR/JAR 25.149(e).
- (2) V_1, in terms of calibrated airspeed, is the takeoff decision speed selected by the applicant; however, V_1 may not be less than V_{EF} plus the speed gained with the critical engine inoperative during the time interval between the instant at which the critical engine is failed, and the instant at which the pilot recognizes and reacts to the engine failure, as indicated by the pilot's initiation of the first action (e.g. applying brakes, reducing thrust, deploying speed brakes) to stop the airplane during accelerate-stop tests.

(b) V_{2MIN}, in terms of calibrated airspeed, may not be less than—
- (1) 1.2 V_S for—
  - (i) Two-engine and three-engine turbopropeller and reciprocating engine powered airplanes; and
  - (ii) Turbojet powered airplanes without provisions for obtaining a significant reduction in the one-engine-inoperative power-on stalling speed;
- (2) 1.15 V_S for—

(I) Turbopropeller and reciprocating engine powered airplanes with more than three engines; and

(ii) Turbojet powered airplanes with provisions for obtaining a significant reduction in the one-engine-inoperative power-on stalling speed; and

(3) 1.10 times V_{MC} established under FAR/JAR 25.149.

(c) V_2, in terms of calibrated airspeed, must be selected by the applicant to provide at least the gradient of climb required by FAR/JAR 25.121(b) but may not be less than—

(1) V_{2MIN}, and

(2) V_R plus the speed increment attained (in accordance with FAR/JAR 25.111 ©(2)) before reaching a height of 35 feet above the takeoff surface.

(d) V_{MU} is the calibrated airspeed at and above which the airplane can safely lift off the ground, and continue the takeoff. V_{MU} speeds must be selected by the applicant throughout the range of thrust-to-weight ratios to be certificated. These speeds may be established from free air data if these data are verified by ground takeoff tests.

(e) V_R, in terms of calibrated airspeed, must be selected in accordance with the conditions of subparagraphs (e)(1) through (4) of this section:

(1) V_R may not be less than—

(i) V_1;

(ii) 105 percent of V_{MC};

(iii)The speed (determined in accordance with FAR/JAR 25.111©(2)) that allows reaching V_2 before reaching a height of 35 feet above the takeoff surface; or

(iv)A speed that, if the airplane is rotated at its maximum practicable rate, will result in a V_{LOF} of not less than 110 percent of V_{MU} in the all-engines-operating condition and not less than 105 percent of V_{MU} determined at the thrust-to-weight ratio corresponding to the one-engine-inoperative condition, (except that in the particular case that lift-off is limited by the geometry of the aeroplane, or by elevator power, the above margins may be reduced to 108% in the all-engines-operating case and 104% in the one-engine-inoperative condition.")$^{\text{JAR-25 ONLY}}$

(2) For any given set of conditions (such as weight, configuration, and temperature), a single value of V_R, obtained in accordance with this paragraph, must be used to show compliance with both the one-engine-inoperative and the all-engines-operating takeoff provisions.

(3) It must be shown that the one-engine-inoperative takeoff distance, using a rotation speed of 5 knots less than V_R established in accordance with subparagraphs (e)(1) and (2) of this section, does not exceed the corresponding one-engine-inoperative takeoff distance using the established V_R. The takeoff distances must be determined in accordance with FAR 25.113 (JAR-25.113(a)(1)).

(4) Reasonably expected variations in service from the established takeoff procedures for the operation of the airplane (such as over-rotation of the airplane and out-of-trim conditions) may not result in unsafe flight characteristics or in marked increases in the scheduled takeoff distances established in accordance with FAR/JAR 25.113(a).

(f) V_{LOF} is the calibrated airspeed at which the airplane first becomes airborne.

(g) V_{FTO}, in terms of calibrated airspeed, must be selected by the applicant to provide at least the gradient of climb required by § 25.121(c), but may not be less than—

(1) 1.18 V_{SR}; and

(2) A speed that provides the maneuvering capability specified in § 25.143(g).

(h) In determining the takeoff speeds V_1, V_R, and V_2 for flight in icing conditions, the values of V_{MCG}, V_{MC}, and V_{MU} determined for non-icing conditions may be used.

FAR/JAR 25.111 Takeoff path – FAR/JAR 25.111 defines the takeoff path and describes the applicable airplane configuration and performance. The FTHWG proposes to amend FAR/JAR 25.111(c) by adding a new subparagraph (5) that specifies which proposed Appendix C, Part 2, ice accretion is to be used for determining the airplane drag in specified airborne segments of the takeoff path. Subparagraph (5) is stated in a conditional sense, relating back to the discriminant criteria of proposed FAR/JAR 25.105(a)(2) that determine whether or not takeoff path performance must be recalculated for flight in icing conditions. It should be emphasized again that the criteria of subparagraph (5) are only applicable to the airborne portions of the takeoff path since it is assumed ice accretion does not begin until lift-off. Additionally, if takeoff path performance is required to be determined for icing conditions by the proposed criteria of FAR/JAR 25.105(a)(2), the takeoff speeds of FAR/JAR 25.107 determined for icing conditions must be used for determining the airplane drag with the ice accretion specified in subparagraph (5) for the particular takeoff path segment. Additionally, the structure of FAR/JAR 25.111(c)(4) has been revised to improve the order of the requirements but the content remains unchanged other than the addition of the connective "and."

FAR/JAR 25.111 Takeoff path

(a) The takeoff path extends from a standing start to a point in the takeoff at which the airplane is 1,500 feet above the takeoff surface, or at which the transition from the takeoff to the en route configuration is completed and a speed is reached at which compliance with FAR/JAR 25.121(c) is shown, whichever point is higher. In addition—

(1) The takeoff path must be based on the procedures prescribed in FAR/JAR 25.101(f);

(2) The airplane must be accelerated on the ground to V_{EF}, at which point the critical engine must be made inoperative and remain inoperative for the rest of the takeoff; and

(3) After reaching V_{EF}, the airplane must be accelerated to V_2.

(b) During the acceleration to speed V_2, the nose gear may be raised off the ground at a speed not less than V_R. However, landing gear retraction may not be begun until the airplane is airborne.

(c) During the takeoff path determination in accordance with paragraphs (a) and (b) of this section—

(1) The slope of the airborne part of the takeoff path must be positive at each point;

(2) The airplane must reach V_2 before it is 35 feet above the takeoff surface and must continue at a speed as close as practical to, but not less than V_2, until it is 400 feet above the takeoff surface;

(3) At each point along the takeoff path, starting at the point at which the airplane reaches 400 feet above the takeoff surface, the available gradient of climb may not be less than—

(i) 1.2 percent for two-engine airplanes;

(ii) 1.5 percent for three-engine airplanes; and

(iii) 1.7 percent for four-engine airplanes;

(4) **The airplane configuration may not be changed, except for gear retraction and propeller feathering,** and no change in power or thrust that requires action by the pilot may be made until the airplane is 400 feet above the takeoff surface; **and**

(5) If FAR/JAR 25.105(a)(2) requires the takeoff path to be determined for flight in icing conditions, the airborne part of the takeoff must be based on the airplane drag:

(i) With the "Take-off ice" accretion defined in Appendix C from a height of 35 feet above the takeoff surface up to the point where the airplane is 400 feet above the takeoff surface; and

(ii) With the "Final Take-off ice" accretion defined in Appendix C from the point where the airplane is 400 feet above the takeoff surface to the end of the takeoff path.

(d) The takeoff path must be determined by a continuous demonstrated takeoff or by synthesis from segments. If the takeoff path is determined by the segmental method—

(1) The segments must be clearly defined and must be related to the distinct changes in the configuration, power or thrust, and speed;

(2) The weight of the airplane, the configuration, and the power or thrust must be constant throughout each segment and must correspond to the most critical condition prevailing in the segment;

(3) The flight path must be based on the airplane's performance without ground effect; and

(4) The takeoff path data must be checked by continuous demonstrated takeoffs up to the point at which the airplane is out of ground effect and its speed is stabilized, to ensure that the path is conservative relative to the continuous path. The airplane is considered to be out of the ground effect when it reaches a height equal to its wing span.

(e) For airplanes equipped with standby power rocket engines, the takeoff path may be determined in accordance with Section II of Appendix E.

<u>FAR/JAR 25.119 Landing climb</u> – FAR/JAR 25.119 is amended by reformatting with introductory text to specify the airplane configuration, thrust setting and gradient requirements, and subparagraphs (a) and (b) revised to require all-engines-operating landing climb performance to be determined for both non-icing conditions and icing conditions. Subparagraphs (a) and (b) each contain a reference to the appropriate paragraph of FAR/JAR 25.125 for the landing climb speed applicable to the conditions. FAR/JAR 25.119(b) also identifies the Appendix C, Part 2, ice accretion to be used in calculating landing climb performance for icing conditions. It should be noted that there are no conditional performance parameters (i.e., increase in V_{SR} or decrease in

climb gradient due to ice) in the proposed changes to FAR/JAR 25.119 - landing climb performance is required to be determined for all transport category airplanes, which codifies what has been standard FAA practice for almost 40 years.

The FTHWG also proposes to amend FAR/JAR 25.119 to harmonize the landing speed requirements. The FTHWG proposes to remove JAR 25.119(b) (per 1g stall rule), which defines the landing climb speed and permits it to be as low as $1.13V_{SR}$ with a further reduction to $1.08V_{SR}$ for four-engined airplanes that have a significant reduction in stall speed due to power application. The FTHWG also proposes to amend FAR 25.119 by specifying the landing climb speed to be "V_{REF}" as opposed to the current wording, which states "not more than V_{REF}." The additional limitation of JAR 25.119(b) for the landing climb speed to be not less than V_{MCL} will be implicitly retained since V_{MCL} is also specified as a limitation on V_{REF} in FAR/JAR 25.125. The FTHWG considers these changes to be appropriate since the landing climb performance is applicable for balked landings, and since the normal procedure for a balked landing is to establish a positive rate of climb before retracting the landing gear and then accelerate the airplane to permit changing the airplane configuration to further reduce drag, it does not seem logical to permit the speed to be reduced below V_{REF} during the landing climb. The FTHWG believes that the small loss of performance that propeller-driven airplanes may suffer without the lower climb speed limit of JAR 25.119(b), due to slightly less net thrust available, will be outweighed by the benefits of standardization. Additionally, the FTHWG is not aware of any close-in obstacle clearance limitations for balked landings that would require the use of a reduced climb speed to increase the climb gradient.

FAR/JAR 25.119 Landing climb: All-engines-operating

In the landing configuration, the steady gradient of climb may not be less than 3.2 percent, with the engines at the power or thrust that is available 8 seconds after initiation of movement of the power or thrust controls from the minimum flight idle to the go-around power or thrust setting;

(a) In non-icing conditions, with a climb speed of V_{REF} determined in accordance with 25.125 (b)(2)(A)

(b) In icing conditions with the "Landing ice" accretion defined in Appendix C and with a climb speed of V_{REF} determined in accordance with 25.125 (b)(2)(B).

FAR/JAR 25.121 Climb: One-engine-inoperative - FAR/JAR 25.121(b) and (c) are reformatted and amended to specify the conditions under which the climb performance described by those subparagraphs is required to be determined for icing conditions in addition to non-icing conditions. Since the climb segments of FAR/JAR 25.121(b) and (c) are part of the takeoff path described in FAR/JAR 25.111, the stall speed and gradient discriminants of proposed FAR/JAR 25.105(a)(2) are applicable and restated in FAR/JAR 25.121(b)(2) and (c)(2) for the landing gear retracted and final takeoff climb segments, respectively. (See the proposal to amend FAR/JAR 25.105 for a detailed discussion of the reasons for selecting these criteria as discriminants.) FAR/JAR 25.121(b)(2)(ii) and (c)(2)(ii) also specify which Appendix C, Part 2 ice accretion is to be used for determining the climb performance in icing conditions for those takeoff climb segments. It should be emphasized that if the climb speed of either of the climb segments described by FAR/JAR 25.121(b) and (c) is required to be increased for icing conditions due to the stall speed of the landing gear retracted takeoff climb configuration increasing by the greater of 3 knots or 3% V_{SR}, the airplane drag used in the computation of climb performance for icing conditions must be computed at the appropriate icing conditions climb speed.

FAR/JAR 25.121(d) has been reformatted to accommodate the addition of a requirement to determine approach climb performance in icing conditions with the "Holding ice" accretion of proposed Appendix C, Part 2. Proposed FAR/JAR 25.121(d)(2)(ii) requires approach climb performance to be determined with the "Holding ice" accretion described in proposed Appendix C, Part 2. Proposed FAR/JAR 25.121(d)(2)(ii) also specifies the criteria for determining the approach climb speed for icing conditions which, unlike the speeds used in the takeoff path, is not based on the relationship between the stall speed for the airplane with and without ice accretion. Instead, the criteria for determining whether the climb speed needs to be redetermined for icing conditions is based on the increase in that speed over the approach climb speed for non-icing conditions; if the climb speed computed using the stall speed determined with the "Holding ice" accretion and the same operating speed factor as used for non-icing conditions does not exceed the climb speed for non-icing conditions by more than the greater of 3 knots CAS or 3% V_{SR}, the non-icing speeds may be used for calculating approach climb performance for icing conditions. Since the approach climb speed will be in the range of 1.2 to $1.4V_{SR}$, which will result in operating speeds greater than 100 knots for the majority of FAR/JAR 25 airplanes, this approach represents a more liberal criteria than the 3 kts./3%V_{SR} discriminant used for takeoff path speeds (e.g., if approach climb speed is $1.25V_{SR}$ and V_{SR}=100 knots (low), 3% of the approach speed is 3.75 knots). The FTHWG considers this small alleviation to be acceptable on the basis that though the one-engine-inoperative approach climb gradient requirement determines the maximum landing weight for most transport category airplanes, it is not related to an operational go-around. If it is necessary to increase the approach climb speed for icing conditions, the airplane drag used in the computation of climb performance for icing conditions must be computed at that speed.

FAR/JAR 25.121 Climb: One-engine-inoperative

(a) *Takeoff; landing gear extended.* In the critical takeoff configuration existing along the flight path (between the points at which the airplane reaches V_{LOF} and at which the landing gear is fully retracted) and in the configuration used in FAR/JAR 25.111 but without ground effect, the steady gradient of climb must be positive for two-engine airplanes, and not less than 0.3 percent for three-engine airplanes or 0.5 percent for four-engine airplanes, at V_{LOF} and with—

(1) The critical engine inoperative and the remaining engines at the power or thrust available when retraction of the landing gear is begun in accordance with FAR/JAR 25.111 unless there is a more critical power operating condition existing later along the flight path but before the point at which the landing gear is fully retracted;

(2) The weight equal to the weight existing when retraction of the landing gear is begun, determined under FAR/JAR 25.111;

(b) *Takeoff; landing gear retracted.* In the takeoff configuration existing at the point of the flight path at which the landing gear is fully retracted, and in the configuration used in FAR/JAR 25.111 but without ground effect:

(1) The steady gradient of climb may not be less than 2.4 percent for two-engine airplanes, 2.7 percent for three-engine airplanes, and 3.0 percent for four-engine airplanes, at V_2 with:

(i) The critical engine inoperative, the remaining engines at the takeoff power or thrust available at the time the landing gear is fully retracted, determined under FAR/JAR 25.111, unless there is a more critical power operating condition existing later along the flight path but before the point where the airplane reaches a height of 400 feet above the takeoff surface; and

(ii) The weight equal to the weight existing when the airplane's landing gear is fully retracted, determined under FAR/JAR 25.111.

(2) The requirements of paragraph (b)(1) of this section must be met:

(i) In non-icing conditions; and

(ii) In icing conditions with the "Take-off ice" accretion defined in Appendix C, if in the configuration of FAR/JAR 25.121(b) with the "Take-off ice" accretion :

(A) The stall speed at maximum takeoff weight is increased by more than the greater of 3 knots CAS or 3% V_{SR}; or

(B) The degradation of the gradient of climb determined in accordance with FAR/JAR 25.121(b) is greater than one-half of the applicable actual-to-net takeoff flight path gradient reduction defined in FAR/JAR 25.115(b).

(c) Final takeoff. In the en route configuration at the end of the takeoff path determined in accordance with FAR/JAR 25.111:

(1) The steady gradient of climb may not be less than 1.2 percent for two-engine airplanes, 1.5 percent for three-engine airplanes, and 1.7 percent for four-engine airplanes, at V_{FTO} with—

(i) The critical engine inoperative and the remaining engines at the available maximum continuous power or thrust; and

(ii) The weight equal to the weight existing at the end of the takeoff path, determined under FAR/JAR 25.111.

(2) The requirements of paragraph (c)(1) of this section must be met:

(i) In non-icing conditions; and

(ii) In icing conditions with the "Final take-off ice" accretion defined in Appendix C, if in the configuration of FAR/JAR 25.121(b) with the "Take-off ice" accretion:

(A) The stall speed at maximum takeoff weight is increased by more than the greater of 3 knots CAS or 3% V_{SR}; or

(B) The degradation of the gradient of climb determined in accordance with FAR/JAR 25.121(b) is greater than one-half of the applicable actual-to-net takeoff flight path gradient reduction defined in FAR/JAR 25.115(b).

(d) *Approach.* In the approach configuration corresponding to the normal all-engines-operating procedure in which V_S for this configuration does not exceed 110 percent of the V_S for the related landing configuration:

(1) The steady gradient of climb may not be less than 2.1 percent for two-engine airplanes, 2.4 percent for three-engine airplanes, and 2.7 percent for four-engine airplanes, with—

(i) The critical engine inoperative, the remaining engines at the go-around power or thrust setting;

(ii) The maximum landing weight;

(iii) A climb speed established in connection with normal landing procedures, but not exceeding 1.4 V_{SR}: and

(iv) Landing gear retracted.

(2) The requirements of paragraph (d)(1) of this section must be met:

(i) In non-icing conditions; and

(ii) In icing conditions with the "Holding ice" accretion defined in Appendix C; the climb speed selected for non-icing conditions may be used if the climb speed for icing conditions, computed in accordance with paragraph (d)(1)(iii) of this section, does not exceed that speed by more than the greater of 3 knots CAS or 3%.

<u>FAR/JAR 25.123 En route flight paths</u> – FAR/JAR 25.123(a) has been amended by adding a minimum speed limitation of $1.18V_{SR}$, which is also the minimum limit on the final takeoff speed (in the same configuration) of FAR/JAR 25.121(c). This addition ensures that the airplane will not experience a decrease in kinetic energy when transitioning from the final takeoff to en route climb segment and reflects the inherent limit speed for showing compliance to the maneuver capability requirements introduced by the 1g stall rule (Ref.: FAR/JAR 25.143(h)).

The icing-related amendments to FAR/JAR 25.123 only affect the paragraphs dealing with one-engine-inoperative performance; it is assumed that failure of a second engine would give flightcrews considerable cause to avoid or depart icing conditions.

FAR/JAR 25.123(a) has been amended to state the conditions under which en route fight path performance must be determined for icing conditions and the proposed Appendix C, Part 2 ice accretion to be used; these criteria are presented in FAR/JAR 25.123(b)(2). Similar to the preceding takeoff path climb performance requirements, speed increase and gradient reduction due to the effects of ice are employed as the discriminant criteria for determining whether en route flight path performance needs to be determined for icing conditions.

Similar to the takeoff path, the en route climb gradient for non-icing conditions is allowed to be reduced by up to one-half the difference between the actual and net flight paths, as defined in FAR/JAR 25.123(b). FAR/JAR 25.123 uses an operating speed discriminant similar to the approach climb of FAR/JAR 25.121(d), only in this case a speed of $1.18V_{SR}$ determined with the "En-route ice" accretion of proposed Appendix C, Part 2 is compared with the en route climb speed selected for non-icing conditions. The basis of this operating speed increase criteria is the fact that propeller-driven airplanes will generally use the minimum allowable operating speeds due to the inverse relationship between thrust and airspeed whereas turbojet-powered airplanes will use a higher speed selected to maximize climb performance. The result of this difference in operating speeds is that turbojets will typically have an approximate 12% V_{SR} margin above the minimum speed at which compliance can be shown with the maneuver capability requirements of FAR/JAR 25.143(h) while the propeller driven airplanes will have no margin. Additionally, due to their slower operating speeds, the propeller-driven airplanes will probably be subjected to increased exposure to icing conditions. The proposed criteria acknowledges the fact that two classes of transport category airplanes exist with significantly different criteria for determining their operating speeds, protecting one class from the negative effects of ice while not unduly penalizing the other. Though this appears to negate one of the basic premises set forth for developing requirements for flight in icing conditions, that all transport category airplanes should be treated the same, the FTHWG believes this differentiation is appropriate since this regulation provides considerable latitude in the selection of the operating speed.

If it is necessary to increase the en route climb speed for icing conditions, the airplane drag used in the computation of climb performance for icing conditions must be computed at that speed.

FAR/JAR 25.123 En route flight paths

(a) For the en route configuration, the flight paths prescribed in paragraphs (b) and (c) of this section must be determined at each weight, altitude, and ambient temperature, within the operating limits established for the airplane. The variation of weight along the flight path, accounting for the progressive consumption of fuel and oil by the operating engines, may be included in the computation. The flight paths must be determined at a speed not less than V_{FTO}, with—
   (1) The most unfavorable center of gravity;
   (2) The critical engines inoperative;
   (3) The remaining engines at the available maximum continuous power or thrust;
   (4) The means for controlling the engine-cooling air supply in the position that provides adequate cooling in the hot-day condition;

(b) The one-engine-inoperative net flight path data must represent the actual climb performance diminished by a gradient of climb of 1.1 percent for two-engine airplanes, 1.4 percent for three-engine airplanes, and 1.6 percent for four-engine airplanes-
   (1) In non-icing conditions; and
   (2) In icing conditions with the "En-route ice" accretion defined in Appendix C, if :
      (i) 1.18V_{SR} with the "En-route ice " accretion exceeds the En-route speed selected in non-icing conditions by the greater of 3 knots CAS or 3% V_{SR}, or
      (ii) The degradation of the gradient of climb is greater than one-half of the applicable actual-to-net flight path reduction defined in paragraph (b) of this section.

(c) For three- or four-engine airplanes, the two-engine-inoperative net flight path data must represent the actual climb performance diminished by a gradient of climb of 0.3 percent for three-engine airplanes, and 0.5 percent for four-engine airplanes.

FAR/JAR 25.125 Landing – FAR/JAR 25.125(a) has been amended to state the conditions under which the landing distance must be determined for icing conditions and the proposed Appendix C, Part 2 ice accretion to be used. Specifically, if V_{REF} determined with the "Landing ice" accretion is greater than V_{REF} in non-icing conditions by more than 5 knots CAS, the landing distance for icing conditions must be determined with the "Landing ice" accretion and at the appropriate V_{REF}, as defined in new FAR/JAR 25.125(b)(2)(B).

The "5 knots CAS" increase criteria has its origin in: 1) Standard certification practice has been to investigate longitudinal controllability to cover operational landing abuse cases where an inadvertent speed decrease below V_{REF} may occur - this investigation has been conducted by showing the airplane can be safely controlled and landed when the airspeed at 50 feet is V_{REF} - 5 knots; 2) Transport category airplanes are typically operated with speed additives to provide gust margins that may or may not be bled off before crossing the threshold; and similarly 3) Many transport category airplanes have been operated with a 5 knot speed additive during final approach to cover for inadvertent speed loss, that has often been carried to the 50 foot point without any indication of a landing distance-related safety problem. In conjunction with the third reason for using a 5 knot discriminant, it should be noted that many of the transport category airplanes with the 5 knot additive are operated under FAR Part 121, which requires that the airplane can be landed and brought to a complete stop in 60% of the available field length, whereas another segment of transport category airplanes are operated under FAR Part 91 and may or may not be operated with this same landing field length margin. 4) A 5 knot increase above the non-contaminated airplane landing reference speed equates to approximately 3% of the 1g stall speed (slightly more than 3% for larger airplanes) for the same configuration, which is consistent with the allowable stall speed tolerance for the takeoff path airplane configurations with ice. In consideration of the information presented above, the FTHWG considers a 5 knot increase in V_{REF} due to ice accretion to be acceptable.

A second constraint on V_{REF} for icing conditions is that it must provide the maneuvering capability required by FAR/JAR 25.143(g) with the "Landing ice" accretion; this entails demonstrating a constant speed 40° banked turn without encountering stall warning.

Existing FAR/JAR 25.125(a)(2), which has been reformatted as proposed FAR/JAR 25.125(b)(2)(A), also requires V_{REF} for non-icing conditions to be not less than the Landing Minimum Control Speed, V_{MCL}, to ensure adequate directional control in the event the critical engine fails during a go-around executed during the approach and landing phase of flight. Similar to V_{MCG} and V_{MCA} for the takeoff phase, the V_{MCL} determined for non-icing conditions is retained as a minimum airspeed limitation on V_{REF} determined for icing conditions. Unlike the takeoff case, this is not explicitly stated but is obvious since proposed FAR/JAR 25.125(b)(2)(B) requires, in part, V_{REF} for icing conditions to be not less than V_{REF} for non-icing conditions, which in turn must be not less than V_{MCL}. To provide assurance that controllability and maneuverability will not be compromised by using the V_{MCL} determined for non-icing conditions as a minimum airspeed limitation on V_{REF} determined for icing conditions, proposed FAR/JAR 25.143(c)(2) and (3) require the applicant to show the airplane will be safely controllable and maneuverable during an approach and go-around, and an approach and landing, with the critical engine inoperative; in the interest of flight test safety, these maneuvers may be accomplished with a simulated engine failure, as noted in the associated advisory material. Consequently, the FTHWG considers the use of the non-icing conditions V_{MCL} to be acceptable as a limitation on V_{REF} for icing conditions.

FAR/JAR 25.125 Landing

(a) The horizontal distance necessary to land and to come to a complete stop (or to a speed of approximately 3 knots for water landings) from a point 50 feet above the landing surface must be determined (for standard temperatures, at each weight, altitude, and wind within the operational limits established by the applicant for the airplane) :

(1) In non-icing conditions

(2) In icing conditions with the "Landing ice" accretion defined in appendix C if V_{REF} in icing conditions is greater than V_{REF} in non-icing conditions by more than 5 knots CAS.

(b) In determining the distance in (a):

(1) The airplane must be in the landing configuration.

(2) A stabilized approach, with a calibrated airspeed of not less than V_{REF}, must be maintained down to the 50 foot height.

(A) In non-icing conditions, V_{REF} may not be less than:

(i) $1.23V_{SR0}$;

(ii) V_{MCL} established under JAR 25.149(f); and

(iii) a speed that provides the maneuvering capability specified in FAR/JAR 25.143(h).

(B) In icing conditions, V_{REF} may not be less than:

(i) the speed determined in paragraph (b)(2)(A) of this section;

(ii) 1.23 V_{SR0} with the landing ice accretion if that speed exceeds V_{REF} selected in non-icing condition by more than 5 knots CAS

(iii) a speed that provides the maneuvering capability specified in FAR/JAR 25.143(h).

(3) Changes in configuration, power or thrust, and speed, must be made in accordance with the established procedures for service operation.

(4) The landing must be made without excessive vertical acceleration, tendency to bounce, nose over, ground loop, porpoise, or water loop.

(5) The landings may not require exceptional piloting skill or alertness.

(c) For landplanes and amphibians, the landing distance on land must be determined on a level, smooth, dry, hard-surfaced runway. In addition—

(1) The pressures on the wheel braking systems may not exceed those specified by the brake manufacturer;

(2) The brakes may not be used so as to cause excessive wear of brakes or tires; and

(3) Means other than wheel brakes may be used if that means—

(i) Is safe and reliable;

(ii) Is used so that consistent results can be expected in service; and

(iii) Is such that exceptional skill is not required to control the airplane.

(d) For seaplanes and amphibians, the landing distance on water must be determined on smooth water.

(e) For skiplanes, the landing distance on snow must be determined on smooth, dry, snow.

(f) The landing distance data must include correction factors for not more than 50 percent of the nominal wind components along the landing path opposite to the direction of landing, and not less than 150 percent of the nominal wind components along the landing path in the direction of landing.

(g) If any device is used that depends on the operation of any engine, and if the landing distance would be noticeably increased when a landing is made with that engine inoperative, the landing distance must be determined with that engine inoperative unless the use of compensating means will result in a landing distance not more than that with each engine operating.

FAR/JAR 25.143 Controllability and Maneuverability - General – As noted in discussions related to takeoff and landing speeds, FAR/JAR 25.143 is amended with the addition of a new paragraph (c) that requires the applicant to show the airplane is safely controllable and maneuverable in three one-engine-inoperative low speed maneuvers with the appropriate ice accretion; these requirements were added to ensure that use of the minimum control speeds determined for non-icing conditions will not result in controllability and maneuverability problems when used as minimum operating speed limits for icing conditions.

FAR/JAR 25.143 is also amended with the addition of paragraph (i), which contains a general icing-related application requirement in subparagraph (1) and a specific icing conditions test in subparagraph (2).

FAR/JAR 25.143(i)(1) states, in part, that "...controllability may be demonstrated with the ice accretion described in Appendix C that is most critical for the particular flight phase." Implicit in this statement is a requirement for compliance to be shown with all of FAR/JAR 25.143 (except paragraphs (b)(1) and (2) that are exempted by proposed FAR/JAR 25.21(g)), with an allowance being made for the applicant to minimize the number of ice accretions to be tested by using the one that is shown to be the most critical for the flight phase under consideration. Subparagraph (1) also adds a requirement for "Sandpaper ice" to be considered in determining the "critical" ice accretion for airplanes with unpowered elevator controls. The thin, rough, layer of ice that is defined as "Sandpaper ice" in the proposed Appendix C, Part 2 has been shown in many cases to have a more detrimental effect on handling characteristics than larger shapes for airplanes with unpowered control systems, in some cases resulting in control surface hinge moment reversals that require the application of extremely high pilot control forces to recover from resulting upsets.

FAR/JAR 25.143(i)(2) adds a requirement that is intended to investigate an airplane's susceptibility to ice-contaminated tailplane stall (ICTS). Several incidents and accidents have been attributed to ICTS, which can be characterized as an actual stalled airflow condition existing, or an elevator hinge moment reversal due to separated flow, on the lower surface of the horizontal stabilizer. ICTS incidents and accidents have typically occurred during landing approaches, with some form of ice accretion on the horizontal stabilizer (tailplane), when selecting increased flap deflections and/or decreasing pitch attitude abruptly, resulting in angle of attack (AoA) increases and required download (lift) increases on the tailplane. The degraded airflow conditions caused by ice accretion result in a reduced tailplane stall AoA and lift capability that is manifested by longitudinal control push force lightening and/or reversal. A flight test method to conservatively determine susceptibility to ICTS by increasing the AoA on an ice contaminated tailplane by inducing a nose down pitch rate has been created involving a pushover to zero-g. The pass/fail criteria proposed for this test is that a longitudinal control push force be required to some 'g' level and that the airplane must remain controllable to zero-g. Some criteria have also included demonstration of a sideslip maneuver with an ice-contaminated tailplane since this has been shown as a more critical ICTS triggering mechanism for some airplanes.

The proposal presented in FAR/JAR 25.143(i)(2) for investigating an airplane's susceptibility to ICTS does not represent a consensus position within the FTHWG; it represents the majority position as determined by a vote of the ARAC member organizations that participated in developing the proposals of this NPRM. As such, alternative proposals for regulatory language with associated justifications are provided in the following paragraphs. Dispositions of the alternative positions are also presented and appropriately identified.

FAR/JAR 25.143 is also amended by the addition of subparagraph (j) to specify tests for ensuring that the airplane has adequate controllability with the ice accretions that exist on the unprotected and protected surfaces prior to normal activation of the ice protection system. In developing these controllability criteria, the FTHWG gave consideration to the temporary nature of this ice accretion and further classified the temporary nature by relating the controllability test requirements to the means of ice detection and whether or not the ice protection system required crew action for activation. The advisory material for Appendix C, Part 2(c) provides guidance for determining the appropriate ice accretion for this testing based on the means of ice detection.

Alternative 1

23 April 1999

Flight Test Harmonization Working Group - Flight In Icing Conditions

JAA/FAA/ALPA Minority Position: **Zero-g pushover maneuver** and Longitudinal Characteristics During Sideslip Maneuvers

Ice contaminated tailplane stall/elevator hinge moment reversal has been a significant factor in accidents occurring in icing conditions. Rapid pitch divergence, significant changes in control forces, pilot surprise factor and possible disorientation in poor visibility that can follow from a tailplane stall/elevator hinge moment reversal can result in loss of pitch control. Coupled with the fact that, due to the nature of the phenomenon, this loss of control will usually occur at low altitude, there is a high probability of an accident.

Historically, the pushover test was usually performed to 0.5g total although this was often done with a high pitch rate and hence there was some overshoot of the 0.5g level. A push force on the elevator control was required to reach this g level. Certification testing and service experience have since shown that testing to 0.5g is not adequate, bearing in mind the relatively high frequency of experiencing 0.5g in operations. Since the beginning of the 1980's or thereabouts, the practice of many Authorities has been to require testing to lower load factors and NPA 25F-219 requires a push force throughout the maneuver to zero g. The FTHWG is agreed that testing should be performed to zero g. However, it is the JAA/FAA/ALPA Minority contention in the FTHWG that a push force should be required to zero g. The Majority position is that reversal of the elevator control force below 0.5g is acceptable within limits.

Reversal of elevator control force versus normal acceleration is not acceptable within the flight envelope. Existing requirements and advisory material addressing elevator control force characteristics (JAR/FAR 25.143(f), 25.255(b)(2) and the ACJ/AC material to 25.143(f)) do not allow force reversals. Furthermore, a survey of JAA/FAA/TC flight test personnel showed that a clear majority did not favor anything less than a push force on the elevator control to zero g.

The Majority position on this item goes some way to addressing the cause of past accidents. However, the method proposed by the Majority of determining the acceptability of a control force reversal is subjective and will lead to inconsistent evaluations. The JAA/FAA/ALPA Minority position is that a push force to zero g with an ice contaminated tailplane is the minimum standard that can be accepted. Zero g is within the flight envelope of the airplane and the criteria recognizes the need to have acceptable handling qualities for operational service when the pilot would not expect any control force reversal. Requiring a push force to zero g also removes subjectivity in the assessment of the airplane's controllability and provides a readily understood criteria of acceptability. Any lesser standard does not give confidence that the problem has been fully addressed or resolved.

Whilst there is no technical disagreement in the FTHWG on the need to address longitudinal control force changes to maintain speed with increasing sideslip angle, and advisory material to 25.143 has been agreed to achieve this, the JAA/FAA/ALPA Minority believe that a specific requirement, as proposed in 25.143(i)(3), is appropriate.

FAA Flight Test Pilot comment on FAA, JAA, ALPA Pushover Position

Reversal of elevator control force versus normal acceleration is not acceptable within the flight envelope. Existing requirements and advisory material addressing elevator control force characteristics (JAR/FAR 25.143(f), 25.255(b)(2) and the ACJ/AC material to 25.143(f)) do not allow force reversals. Furthermore, a survey of JAA/FAA/TC flight test personnel showed that a clear majority did not favor anything less than a push force on the elevator control to zero g.

A nose down pitch upset is, of course, arrested by a natural and familiar nose up longitudinal control input; but if the upset is caused by an ice contaminated tailplane, this upset may be unexpected and occur at low altitude during normal procedures to configure the airplane for approach and landing. There is no other available primary control input to alleviate forces in the pitch axis as there is with rudder to supplement aileron to recover from a roll upset. This fact accentuates the need for applied or induced control forces in all flight regimes to be in a manner that all pilots are accustomed to and expect. Consequently, the requirement to have no longitudinal control force reversal during the ice-contaminated tailplane stall evaluation pushover maneuver is justified.

The term "controllability", if it is to be used in this case, must have a definition that is not only understandable but irrefutable. In an attempt to use the concept of a specific quantitative test for "controllability" in evaluations of the pushover maneuver, the following is offered as an example:

> Controllability must be maintained throughout the maneuver down to zero-g or the minimum load factor that can be achieved. The ability to control pitch attitude and load factor <u>should</u> be maintained with no sudden stick force reversal. Gradual stick force reversals within this range of load factors will be acceptable provided that any pitch down characteristic is mild and does not require exceptional pilot skill to control. After a delay of at least one second at zero-g or the minimum load factor that can be achieved, it must be possible to promptly recover to level flight from the maneuver with not greater than 1.5 g load factor without configuration change and without exceeding 50 pounds of pull force.

(This specified time delay before recovery is to standardize the flight test procedure and is consistent with autopilot hard-over testing. Fifty pounds is the "one hand" force criteria stated in JAR 25.143.)

In a survey, several FAA Flight Test Pilots stated that the procedure and criteria in this paragraph, even though an attempt was made to be quantitative, is still too vague and will lead to differing interpretations across projects and flight test teams. They stated that a push force to zero-g represents a suitable level of controllability that would be consistently interpreted. Several other commenters stated that no force reversals would be acceptable to zero-g based on realistic operational concerns of tailplane stalls due to turbulence and gusts, and the element of aircrew surprise with ensuing control difficulties.

Majority Disposition of FAA, JAA, ALPA Pushover Position

Historically, the pushover test was usually performed to 0.5g rather than zero g. As practiced by Transport Canada, this demonstration was done with a high pitch rate and hence there was significant overshoot of the 0.5g level down to around .25g or less. This was a controllability test involving an abrupt push followed by a pull to recover. The intent was not to reach a specific g level below 0.5g but rather to show that the pilot could effect a satisfactory recovery. This has proven to be an acceptable test technique. To date, airplanes evaluated with this technique have been satisfactory in service.

Since the beginning of the 1980's or thereabouts, the practice of many Authorities has been to require testing to lower load factors. This evolved until the introduction of NPA 25F-219 which not only requires testing to zero g but also requires a push force throughout the maneuver to zero g. The FTHWG Majority argued that a zero g pushover is an improbable condition, going well beyond any operational maneuver, which does not properly represent gusts, pitch rate, elevator position, and other factors which may contribute to tailplane stalls. Also, since the NPA requirement was developed for a specific turboprop, and motivated by service experience on turboprop airplanes, other requirements were proposed for other types. After much debate, the Majority eventually accepted use of the pushover maneuver, within limits, as a compromise means of showing that an adequate safety margin exists. However, it is the Majority position that requiring a push force to zero g is excessive.

The Flight Test Guide, AC 25-7A, defines the boundaries of various flight envelopes. With regard to minimum load factor with flaps down, the Normal Flight Envelope (NFE) goes to 0.8g; the Operational Flight Envelope (OFE) to 0.5g; and the Limit Flight Envelope (LFE) to 0g. Conceptually, the boundaries of the OFE are as far as the pilot is expected to go intentionally, while the LFE is based on structural or other limits which should not be exceeded. Between the OFE and the LFE, it is understood that handling qualities may be degraded, but the airplane must remain controllable and it must be possible to avoid exceeding the limit load factor (see FAR/JAR 25.143(b)). The Majority position is consistent with these concepts.

The Minority cite existing regulations which do not allow force reversals for the en-route configuration (e.g. FAR/JAR 25.143(f), 25.255(b)(2)). In practice, the certification tests for these rules do not cover the full structural limit flight envelope, but rather a reasonable range of load factor sufficient for normal operations. For example, in the en-route configuration, where the limit minimum load factor usually is -1g, ACJ No. 2 to JAR 25.143(f) states, "assessment of the characteristics in the normal flight envelope involving normal accelerations from 1g to 0g, will normally be sufficient." With flaps up, 0g is the midpoint between the limit load factor and the trim point. The corresponding points for flaps down are 0g for the limit load factor and 0.5g for the midpoint assessment of characteristics. The Majority are concerned that requiring a push force to zero g means this limit load factor will be routinely exceeded in flight tests.

The zero g pushover is not like typical stability tests where it is possible to establish steady state conditions and measure a repeatable control force. The pushover is an extremely dynamic maneuver lasting only a few seconds and involving high pitch rates in both directions. There will always be variability due to pilot technique. The pilot may pull slightly before reaching zero g to reduce the nose-down pitch rate and anticipate the recovery. This makes it impossible to distinguish the force required to reach a given g level from the force applied by the pilot to modulate the pitch rate. At critical conditions, airplanes which meet the Minority criterion still require a significant pull force to recover. The Majority position sets a 50 pound limit on the total control force to recover promptly. This ensures that the combination of the force to halt the nose-down pitch rate, the force due to any hinge moment reversal, and the force to establish a satisfactory nose-up pitch rate for recovery is controllable with one hand. The 50 pound limit is a readily understood criterion of acceptability which is already applied in several other rules. The effect of data scatter and variations in pilot technique is that marginal airplanes will exceed the 50 pound limit too often, and will not pass.

The Minority position would legislate against an entire class of airplanes, namely light to medium business jets with trimmable stabilizers and unpowered elevators. Many of these airplanes exhibit a mild control force reversal between 0g and 0.5g which is easily controllable. The Minority requirement to push to zero g would reduce the stabilizer incidence available for trim by two to four degrees, requiring either a larger stabilizer (by 20 to 40%) or other design changes. The cost of these changes is not justified by any safety benefit as these airplanes are not the types having ICTS accidents.

Furthermore, the proposed section 25.143(i)(1) requires sandpaper ice be considered if the elevator is unpowered regardless of the ice protection system. Many of the business jets are equipped with anti-ice systems which prevent ice formation on the stabilizer leading edge when operated normally. Thus the jets would be evaluated under more critical assumptions (anti-ice off) than the types which have had accidents (de-ice on).

Ice contaminated tailplanes retain normal linear characteristics until the onset of flow separation. The separation causes the hinge moment coefficient to slope gradually from one level to another over a range of 4 to 10 degrees angle of attack. With the elevator down, the hinge moment coefficient changes sign at an angle of attack in this range which results in the control force reversal from a push to a pull. On a particular business jet with a relatively small elevator, this results in a gradually increasing pull force from zero at about 0.4g to 25 lb. at 0g.

On airplanes with large elevators, especially those with long chords, the elevator control forces resulting from a stalled tail can be very high, even exceeding the pilots' strength capability. For example, assume the elevator dimensions of the previous example are scaled up by a factor of 2. The elevator chord is then doubled, the area is quadrupled, and a given hinge moment coefficient results in 8 times as much control force. If the control force in the previous example was 25 pounds at zero g, the control force for this larger elevator would be 200 pounds. These examples illustrate how the size and design of elevators for certain airplanes determine whether the control forces would be acceptable or hazardous. The Majority proposed test criteria would identify those airplanes with the hazardous characteristics.

Results of the NASA Tailplane Icing Program provide a basis for assessing the requirements. Flight tests were conducted in which a test airplane performed a series of pushovers and other maneuvers with and without ice accretions. Even without ice accretions, reversed control forces were sometimes experienced in the pushover maneuvers for some configurations. With the ice accretions, control forces exceeding 100 pounds were experienced in some of the pushovers although the airplane remained controllable. In one test, a departure from controlled flight occurred during a power transition with a critical ice shape and flaps 40. This event involved a sudden nose-down pitch-over from 1g flight reminiscent of the ICTS accident scenarios. The same ice shape had degraded pushover characteristics to the point that a 50 pound pull was required to recover from 0g with flaps 10 and 100 pounds was required with flaps 20. Hence, the Majority criteria provide an adequate safety margin and would have identified the aircraft as unacceptable before it ever got to the flaps 40 configuration which lost control.

The Majority position is the right balance between cost and benefit. It is adequate to ensure against uncontrollable tailplane stalls. The Majority criteria, combined with measures to ensure proper operation of the ice protection systems, would have prevented the ICTS accidents. The

Minority position would impose an unnecessary burden on some manufacturers and their customers.

Alternative 2

Draft 2
29 April 1999

Flight Test Harmonization Working Group - Flight In Icing

Minority Position (Transport Canada): Zero 'g' Pushover Maneuver and Longitudinal Characteristics During Sideslip Maneuvers

Zero 'g' Pushover Maneuver

Ice contaminated tailplane stall/elevator hinge moment reversal has been a significant factor in accidents occurring in icing conditions. Rapid pitch divergence, significant changes in control forces, pilot surprise factor and possible disorientation in poor visibility that can follow from a tailplane stall/elevator hinge moment reversal can result in loss of pitch control. Coupled with the fact that, due to the nature of the phenomenon, this loss of control will usually occur at low altitude, there is a high probability of an accident.

Transport Canada advisory material dating back to the mid 1980's specified that +/- 0.5 'g' longitudinal control had to be demonstrated. In practice, the demonstration was done in a fairly abrupt maneuver which generated a significantly higher transient pitch rate than that associated with the steady normal acceleration. The minimum normal acceleration obtained was usually around 0.25 'g' or less. It was considered that the pitch rate aspect was just as important as the actual normal acceleration in determining whether there were unsafe characteristics associated with tailplane stall. No pass/fail criteria were provided in the Transport Canada guidance except that the characteristics had to be satisfactory.

The accident record on ice contaminated tailplane stall indicates that a significant factor was the surprise to pilots of an abrupt hinge moment reversal and the magnitude of the control force required to recover the airplane to a normal 1 'g' condition. The majority position recognizes this controllability issue by limiting the amount of pull force required to promptly recover the airplane from a 0.0 'g' condition to 50 lbf pull force. In addition, recognizing that positive stability is also important, the majority position requires a push force down to 0.5 'g'.

Accident data available to Transport Canada indicates that aircraft involved in incidents and/or accidents incurred a tailplane stall at approximately 0.3/0.4 'g'.

Based on this data and Transport Canada's past practice, the majority proposal appears reasonable except that the issue of pitch rate is not specifically identified in the criteria. It is recognized that combining pitch rate with a normal acceleration in a requirement is probably too complex, especially for the wide range of aircraft designs encompassed by FAR/JAR 25. Hence Transport Canada considers that if the requirement is only going to specify a 'g' level, then 0.5 'g' for positive stability is inadequate. A value of 0.25 'g' is considered to be a compromise proposal between 0.5 'g' which is the majority position and 0.0 'g' which is the minority position held by the FAA/JAA/ALPA.

Transport Canada considers the majority proposal is acceptable with the following change:

> "*...It must be shown that a push force is required throughout the maneuver down to 0.25 'g' load factor...*"

Majority Disposition of Transport Canada Pushover Position

The Transport Canada position offers a compromise between the other two positions by specifying 0.25g for the push force requirement. The spirit of compromise is appreciated, however, it still entails some economic impact and has the disadvantage that 0.25g is not related to existing definitions of flight envelopes.

The Transport Canada position recognizes the importance of pitch rate. The Majority appreciate that pitch rate is a significant factor. An abrupt nose-down control input is required to reach zero g. The Majority believe that testing to zero g ensures high pitch rates are evaluated adequately without the complication of specifying a pitch rate requirement.

The zero g maneuver does not treat all airplanes equally with respect to pitch rate. Airplanes with lower landing speeds will be required to pitch at a much higher rate to attain zero g and experience a proportionately higher tail angle of attack. In some cases the pitch rate could be unreasonably high. Therefore, a proposal to set upper and lower limits on pitch rates required for the pushover would be preferable to changing the g level for the push force requirement.

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2 Longitudinal Characteristics During Sideslip Maneuvers

Transport Canada considers it reasonable to expect that there are no anomalies in longitudinal control force during sideslip maneuvers. This aspect has been of concern to some accident investigators and regulatory personnel. At one time it was proposed by the FAA that pushover maneuvers be conducted while in sideslips. Transport Canada considered that this requirement was excessive but recognizing the concern, supported an additional requirement which would specifically assess longitudinal control stick forces while in sideslip maneuvers. Transport Canada considers that a technical consensus was reached on the proposed requirement and the difference with the majority position appears to be whether the requirement appears in advisory material or in the proposed rule.

Transport Canada considers that this is a specific evaluation requirement and hence it is appropriate to place it in the rule rather than in an AC. It is recognized that AC material may also be needed.

Consequently Transport Canada concurs with the minority FAA/JAA/ALPA position and proposes that the following requirement be added:

"Changes in longitudinal control force to maintain speed with increasing sideslip angle must be progressive with no reversals or sudden discontinuities."

Majority Disposition of TC Position on Longitudinal Characteristics During Sideslips

The FTHWG agreed that longitudinal control forces in sideslips could be important. FAA/ JAA/ ALPA and Transport Canada consider there should be a rule concerning this. The Majority consider this aspect is best included in advisory material to alert evaluation pilots to a possible concern. The consensus position had been reached on proposed language for the advisory material. When these same words were proposed as a rule it was the Majority opinion that they do not adequately define unacceptable characteristics and could be misinterpreted. At this time there does not appear to be sufficient data to establish criteria that are specific enough to stand as a rule.

FAR/JAR 25.143 Controllability and Maneuverability - General

(a) The airplane must be safely controllable and maneuverable during-
(1) Takeoff;
(2) Climb;
(3) Level flight;
(4) Descent; and
(5) Landing.

(b) It must be possible to make a smooth transition from one flight condition to any other flight condition without exceptional piloting skill, alertness, or strength, and without danger of exceeding the airplane limit-load factor under any probable operating conditions, including-
(1) The sudden failure of the critical engine;
(2) For airplanes with three or more engines, the sudden failure of the second critical engine when the airplane is in the en route, approach, or landing configuration and is trimmed with the critical engine inoperative; and
(3) Configuration changes, including deployment or retraction of deceleration devices.

(c) It must be shown that the airplane is safely controllable and maneuverable with the critical ice accretion appropriate to the phase of flight defined in Appendix C, and with the critical engine inoperative and its propeller (if applicable) in the minimum drag position: -

(1) At the minimum V_2 for take-off;

(2) During an approach and go-around;

(3) During an approach and landing.

(d) The following table prescribes, for conventional wheel type controls, the maximum control forces permitted during the testing required by paragraphs (a) through (c) of this section:

Values in pounds of force as applied to the control wheel or rudder pedals.	Pitch	Roll	Yaw
For short term application for pitch and roll control – two hands available for control	75	50	-
For short term application for pitch and roll control – one hand available for control	50	25	-
For short term application for yaw control	-	-	150
For long term application	10	5	20

(e) Approved operating procedures or conventional operating practices must be followed when demonstrating compliance with the control force limitations for short term application that are prescribed in paragraph (c) of this section. The airplane must be in trim, or as near to being in trim as practical, in the preceding steady flight condition. For the takeoff condition, the airplane must be trimmed according to the approved operating procedures.

(f) When demonstrating compliance with the control force limitations for long term application that are prescribed in paragraph (d) this section, the airplane must be in trim, or as near to being in trim as practical.

(g) When maneuvering at a constant airspeed or Mach number (up V_{FC}/M_{FC}), the stick forces and the gradient of the stick versus maneuvering load factor must lie within satisfactory limits. The stick forces must not be so great as to make excessive demands on the pilot's strength when maneuvering the airplane, and must not be so low that the airplane can easily be overstressed inadvertently. Changes of gradient that occur with changes of load factor must not cause undue difficulty maintaining control of the airplane, and local gradients must not be so low as to result in a danger of overcontrolling.

(h) The maneuvering capabilities in a constant speed coordinated turn at forward center of gravity, as specified in the following table, must be free of stall warning or other characteristics that might interfere with normal maneuvering:

CONFIGURATION	SPEED	MANEUVERING BANK ANGLE IN A COORDINATED TURN	THRUST/POWER SETTING
TAKEOFF	V_2	30°	ASYMMETRIC WAT-LIMITED.[1]
TAKEOFF	V_2 + XX[2]	40°	ALL-ENGINES-OPERATING CLIMB.[3]
ENROUTE	V_{FTO}	40°	ASYMMETRIC WAT-LIMITED.[1]
LANDING	V_{REF}	40°	SYMMETRIC FOR -3° FLIGHT PATH ANGLE

(1) A combination of weight, altitude and temperature (WAT) such that the thrust or power setting produces the minimum climb gradient specified in § 25.121 for the flight condition.
(2) Airspeed approved for all-engines-operating initial climb.
(3) That thrust or power setting which, in the event of failure of the critical engine and without any crew action to adjust the thrust or power of the remaining engines, would result in the thrust or power specified for the take-off condition at V_2, or any lesser thrust or power setting that is used for all-engines-operating initial climb procedures.

(i) When demonstrating compliance with FAR/JAR 25.143 in icing conditions -

(1) Controllability may be demonstrated with the ice accretion described in Appendix C that is most critical for the particular flight phase . For airplanes with unpowered elevator controls, "Sandpaper ice" must be considered in determining the critical ice accretion; and

(2) The airplane must be controllable in a pushover maneuver down to zero-G or the lowest load factor obtainable if limited by elevator power. It must be shown that a push force is required throughout the maneuver down to 0.5g. It must be possible to promptly recover from the maneuver without exceeding 50 pounds pull control force.

(j) For flight in icing conditions prior to normal operation of the ice protection system, the following apply:

(1) If normal operation of any ice protection system is dependent upon visual recognition of a specified ice accretion on a reference surface, the requirements of FAR/JAR 25.143 are applicable with the ice accretion defined in Appendix C, Part 2(c).

(2) If normal operation of any ice protection system is dependent upon means of recognition other than that defined in paragraph (j)(1) of this section, it must be shown that the airplane is controllable in a pull-up maneuver up to 1.5g and there is no longitudinal control force reversal during a pushover maneuver down to 0.5g with the ice accretion defined in Appendix C, Part 2(c).

<u>FAR/JAR 25.207 Stall warning</u> – FAR/JAR 25.207(b) is amended to require stall warning to be provided by the same means in icing conditions as it is in non-icing conditions. Another approach that was considered by the FTHWG was that since airflow separation will begin at a lower angle of attack with ice accretions on the wing leading edge, it is reasonable to assume that pre-stall buffet will occur early enough to give the pilot sufficient warning of impending stall. This approach was not adopted for several reasons, the most overriding being the human factors aspects that would result from pilots being trained to recognize stall warning by two different means. Considering that one of the premises the FTHWG assumed in developing the proposed regulatory changes and guidance material is that the probability of icing conditions is one, adequate stall warning should be provided and it is logical that it should be provided by the same means as for non-icing conditions, in the same sense that current FAR/JAR 25.207(b) requires stall warning to be provided by a warning device for all airplane flap/landing gear configurations if it is used to provide stall warning.

A new paragraph FAR/JAR 25.207(e) specifies the stall warning criteria that must be met in icing conditions, including the Appendix C ice accretion applicable to the airplane high-lift configuration. The proposed criteria require an investigation of stall warning margin for straight and turning flight with an entry rate of 1 kt/sec. The stall warning settings established for the airplane without ice accretions may be retained for operation in icing conditions provided they are still adequate to prevent stalling if the pilot takes no action to recover until three seconds after the initiation of stall warning. In developing this criteria, the FTHWG took into consideration the types of transport category airplanes that have been in icing-related accidents as a result of stalling one or both wings; that subgroup of airplanes were not equipped with uninterrupted operation thermal anti-ice systems and generally experienced a considerable decrease in the stall angle of attack due to the effect of ice on the unprotected surfaces combined with ice on the protected surfaces during those periods when a cyclic ice protection system was not operating (intercycle ice). The proposed criteria will likely require a reset of the stall warning system for icing conditions on those airplanes, while having a lesser impact on the subgroup of transport category airplanes that have demonstrated safe flight in icing conditions. Since all modern transport category airplanes use some type of artificial stall warning system (i.e., stick shaker or combined aural and visual warning), and since three seconds is considered adequate for a trained pilot response, the FTHWG considers this icing-specific stall warning definition to be acceptable.

The FTHWG considered requiring an investigation of stall warning in icing conditions at entry rates greater than 1 kt./sec. (as required for non-icing conditions) with a one second delay before pilot action to recover, the reduced delay being associated with the assumption that a high entry rate would most likely be associated with maneuvers such as collision avoidance. The FTHWG did not propose such criteria because most artificial stall warning systems incorporate a phase advance that decreases the angle of attack for stall warning activation as the rate at which angle of attack increase becomes higher , as would occur with a high entry rate, thus making the slow entry rate with longer delay time the critical case.

The FTHWG determined the "Holding ice" accretion to be appropriate for investigating the stall warning margin for those high-lift configurations used from the actual holding maneuver through the descent to either a landing or go-around. The "Holding ice" accretion of proposed Appendix C, Part 2, is representative of the ice accretion that has traditionally been employed by the FAA in icing certifications; it is the result of up to a 45 minute hold in the Continuous Maximum Icing conditions defined in Appendix C, Part 1, that is assumed to remain on the airframe during the descent and landing. Consistent with the use of the "Holding ice" accretion for evaluating stall warning in the en-route, approach, landing, and go-around configurations, the proposed Appendix C, Part 2, definitions of the ice accretions appropriate to the en-route and landing configurations permit the use of "Holding ice" in lieu of defining additional shapes.

Proposed FAR/JAR 25.207(e)(2) permits the use of the more critical of the "Takeoff ice" or "Final takeoff ice" accretion to be used in evaluating the stall warning margin for the takeoff configuration. The takeoff configuration is treated separately due to the different icing atmosphere defined for takeoff (see Appendix C, Part 1) and due to a more limited exposure time. As noted in proposed Appendix C, Part 2, the "Holding ice" accretion may also be used in lieu of the "Takeoff ice" and "Final takeoff ice" accretions if it is shown to be more critical; this is particularly important since it has been shown that the ice accretion having the most detrimental effect on airplane handling characteristics may not be the large, craggy, multi-horned shape that one would intuitively expect but may instead be a thin, rough layer of ice that initially accretes.

FAR/JAR 25.207(f) is amended to clarify that the pilot should use the same stall recovery techniques for the airplane with ice accretions as used for demonstrating compliance with FAR/JAR 25.207 in non-icing conditions. This requirement is based on human factors' considerations for minimizing the number of variations in a common procedure; the operational pilot should not be tasked with deciding what procedure to employ in a high workload environment, such as stall warning, that requires decisive action.

Although the stall warning criteria of FAR/JAR 25.207(c) and (d) for non-icing conditions are exempted for icing conditions in new FAR/JAR 25.21(g), a specific reference to FAR/JAR 25.207(e), which specifies the stall warning criteria for icing conditions, is contained in the sentence that has been added to FAR/JAR 25.207(b) to address the means of stall warning in icing conditions. Since FAR/JAR 25.207(e) prescribes the Appendix C ice accretions that must be used in evaluating stall warning for operation in icing conditions, the requirements of FAR/JAR 25.207(h)(2), which permit a different means of stall warning for evaluating the airplane with the ice accretion prior to normal ice protection system operation, represent the specific application of a stand-alone requirement and do not contradict other stall warning requirements proposed for icing conditions.

FAR/JAR 25.207 is amended by the addition of subparagraph (h) to specify the stall warning margins that must exist with the ice accretions that exist on the unprotected and protected surfaces prior to normal activation of the ice protection system. In developing these stall warning criteria, the FTHWG gave consideration to the temporary nature of this ice accretion and further classified the temporary nature by relating the stall warning margin to the means of ice detection and whether or not the ice protection system required crew action for activation. The FTHWG had particular concern for airplanes where the means of ice detection is visual recognition of a specified ice accretion on a reference surface; as a result FAR/JAR 25.207(h)(1) requires the stall warning for these airplanes to be the same as that provided for operation in icing conditions (i.e., FAR/JAR 25.207 except paragraphs (c) and (d)). For airplanes that use other means of ice detection, FAR/JAR 25.207(h)(2) provides distinct stall warning criteria that also take into account the temporary nature of the ice accretion prior to normal ice protection system operation. As previously stated, due to the self-contained nature of FAR/JAR 25.207(h)(2), the stall warning requirements of that paragraph do not conflict with other stall warning requirements established for other phases of flight in icing conditions. The advisory material for proposed Appendix C, Part 2(c) provides guidance for determining the appropriate ice accretion for this testing based on the means of ice detection.

FAR/JAR 25.207 Stall warning

(a) Stall warning with sufficient margin to prevent inadvertent stalling with the flaps and landing gear in any normal position must be clear and distinctive to the pilot in straight and turning flight.

(b) The warning must be furnished either through the inherent aerodynamic qualities of the airplane or by a device that will give clearly distinguishable indications under expected conditions of flight. However, a visual stall warning device that requires the attention of the crew within the cockpit is not acceptable by itself. If a warning device is used, it must provide a warning in each of the airplane configurations prescribed in paragraph (a) of this section at the speed prescribed in paragraph (c) of this section. **For flight in icing conditions, the stall warning prescribed in paragraph (e) of this section must be provided by the same means as the stall warning for flight in non-icing conditions.**

(c) When the speed is reduced at rates not exceeding one knot per second, stall warning must begin, in each normal configuration, at a speed, V_{SW}, exceeding the speed at which the stall is identified in accordance with § 25.201(d) by not less than five knots or five percent CAS, whichever is greater. Once initiated, stall warning must continue until the angle of attack is reduced to approximately that at which stall warning began.

(d) In addition to the requirement of paragraph (c) of this section, when the speed is reduced at rates not exceeding one knot per second, in straight flight with engines idling and at the center-of-gravity position specified in § 25.103(b)(5), V_{SW}, in each normal configuration, must exceed V_{SR} by not less than three knots or three percent CAS, whichever is greater.

(e) In icing conditions, when the speed is reduced at decelerations of up to 1 kt/sec, the stall warning margin in straight and turning flight must be sufficient to allow the pilot to prevent stalling when recovery, using the same test technique as for the non-contaminated airplane, is initiated not less than 3 seconds after the onset of stall warning, with -
(1) The "Holding ice" accretion described in Appendix C for the en-route, holding, approach, landing, and go-around high-lift configurations; and
(2) The more critical of the "Take-off ice" and "Final Take-off ice" accretions described in Appendix C for each high-lift configuration used in the take-off phase.

(f) The stall warning must be sufficient to allow the pilot to prevent stalling (as defined in § 25.201(d)) when recovery is initiated not less than one second after the onset of stall warning in slow-down turns with at least 1.5g load factor normal to the flight path and airspeed deceleration rates of at least 2 knots per second, with the flaps and landing gear in any normal position, with the airplane trimmed for straight flight at a speed of 1.3 V_{SR}, and with the power or thrust necessary to maintain level flight at 1.3 V_{SR}. **When demonstrating compliance with this paragraph with ice accretions, the same test technique as for the airplane without ice accretions must be used for recovery.**

(g) Stall warning must also be provided in each abnormal configuration of the high lift devices that is likely to be used in flight following system failures (including all configurations covered by Airplane Flight Manual procedures).

(h) For flight in icing conditions prior to normal operation of the ice protection system, the following apply:

(1) If normal operation of any ice protection system is dependant upon visual recognition of a specified ice accretion on a reference surface, the requirements of 25.207 except (c) and (d) are applicable with the ice accretion defined in Appendix C, Part 2(c).
(2) If normal operation of any ice protection system is dependent upon means of recognition other than that defined in paragraph (h)(1) of this section, when the speed is reduced at decelerations of up to 1 kt/sec, the stall warning margin in straight and turning flight must be sufficient to allow the pilot to prevent stalling when recovery, using the same test technique as for the non-contaminated airplane, is initiated not less than 1 second after the onset of stall warning, with the ice accretion defined in Appendix C, Part 2(c).

FAR/JAR 25.237 Wind velocities – FAR/JAR 25.237(a) is amended with the addition of a requirement to determine a landing crosswind component for landplanes and amphibians in icing conditions. This is in addition to the existing requirement for non-icing conditions, with appropriate editorial changes to retain correct paragraph structure and specifically denote "non-icing" and "icing" conditions. FAR/JAR 25.237(a) is also amended to state that the crosswind component established for takeoff without ice accretions may be used for takeoffs conducted in icing conditions. A review of certification data for existing transport category airplanes showed that directional control was not detrimentally affected by ice accretions on the leading edge of the vertical stabilizer. This may be attributed to some designs incorporating leading edge protection and others compensating for the accretion of ice during an extended holding condition that will remain on the airplane through descent and landing. Since the FTHWG has defined and justified in-flight icing conditions as not beginning until lift-off, and since the amount of ice accretion during the takeoff phase will be less than the "Landing ice" accretion of Appendix C, Part 2, the FTHWG does not consider it necessary to demonstrate a separate crosswind velocity for takeoff with an ice accretion.

FAR/JAR 25.237 Wind velocities

(a) For landplanes and amphibians, **the following applies**:
(1) A 90-degree cross component of wind velocity, demonstrated to be safe for takeoff and landing, must be established for dry runways and must be at least 20 knots or 0.2 V_{S0}, whichever is greater, except that it need not exceed 25 knots.
(2) The crosswind component for takeoff established without ice accretions is valid in icing conditions.
(3) The landing crosswind component must be established for:
(i) non-icing conditions, and
(ii) icing conditions with the "Landing ice" accretion defined in Appendix C.

(b) For seaplanes and amphibians, the following applies:
(1) A 90-degree cross component of wind velocity, up to which takeoff and landing is safe under all water conditions that may reasonably be expected in normal operation, must be established and must be at least 20 knots or 0.2 Vs0, whichever is greater, except that it need not exceed 25 knots.
(2) A wind velocity, for which taxiing is safe in any direction under all water conditions that may reasonably be expected in normal operation, must be established and must be at least 20 knots or 0.2 V_{S0}, whichever is greater, except that it need not exceed 25 knots.

<u>FAR/JAR 25.253 High-speed characteristics</u> – FAR/JAR 25.253 is amended to add a new paragraph (c) that provides a definition of the *Maximum speed for stability characteristics, V_{FC}/M_{FC}*, specifically for icing conditions. A review of certification data showed that none of the flight tests for which V_{FC}/M_{FC} is an upper bound had been conducted above 300 knots CAS with artificial ice accretions. One reason for not exceeding 300 knots CAS was the difficulty and cost of fabricating ice accretions and attachment methods that would ensure their integrity at such high speeds. A second, more important reason was the fact that the same airloads that make it difficult to retain artificial ice shapes also result in natural ice shapes separating from airfoil leading edges at high speeds. The FTHWG considers these to be reasonable justifications for specifying a maximum value for V_{FC} of 300 knots CAS for showing compliance with the referenced handling characteristics requirements with ice accretions. Since the group of airplanes defined as "transport category" encompasses a number of configurations with differing propulsive means, the proposed FAR/JAR 25.253(c) recognizes that not all transport category airplanes will have a V_{FC}/M_{FC} as high as 300 knots CAS; consequently, an allowance is provided for V_{FC} with ice accretions to be the lower of 300 knots CAS, V_{FC} without ice accretions (from FAR/JAR 25.253(b)), or any lower airspeed at which the applicant can demonstrate the airplane will be free of ice accretions.

FAR/JAR 25.253 High-speed characteristics

(a) Speed increase and recovery characteristics. The following speed increase and recovery characteristics must be met:
(1) Operating conditions and characteristics likely to cause inadvertent speed increases (including upsets in pitch and roll) must be simulated with the airplane trimmed at likely cruise speed up to

V_{MO}/M_{MO}. These conditions and characteristics include gust upsets, inadvertent control movements, low stick force gradient in relation to friction, passenger movement, leveling off from climb, descent from Mach to airspeed limit altitudes.

(2) Allowing for pilot reaction time after effective inherent or artificial speed warning occurs, it must be shown that the airplane can be recovered to a normal altitude and its speed reduced to V_{MO}/M_{MO}, without-

(I) Exceptional piloting strength or skill;

(ii) Exceeding V_D/M_D, V_{DF}/M_{DF}, or the structural limitations; and

(iii) Buffeting that would impair the pilot's ability to read the instruments or control the airplane for recovery.

(3) With the airplane trimmed at any speed up to V_{MO}/M_{MO}, there must be no reversal of the response to control input about any axis at any speed up to V_{DF}/M_{DF}. Any tendency to pitch, roll, or yaw must be mild and readily controllable, using normal piloting techniques. When the airplane is trimmed at V_{MO}/M_{MO}, the slope of the elevator control force versus speed curve need not be stable at speeds greater than V_{FC}/M_{FC}, but there must be a push force at all speeds up to V_{DF}/M_{DF} and there must be no sudden or excessive reduction of control force as V_{DF}/M_{DF} is reached. (Adequate roll capability to assure a prompt recovery from a laterally upset condition must be available.)[JAR-25 ONLY]

((4) Reserved.)[JAR-25 ONLY]

((5) *Trim change due to airbrake selection.* With the aeroplane trimmed at VMO/MMO, extension of the airbrakes at speeds above VMO/MMO, over the available range of movements of the pilots control must not result in an excessive positive load factor with the stick free, and any nose-down pitching moment must be small.)[JAR-25 ONLY]

(b) *Maximum speed for stability characteristics, V_{FC}/M_{FC},* V_{FC}/M_{FC} is the maximum speed at which the requirements of FAR/JAR 25.143(**g**), 25.147(e), 25.175(b)(1), 25.177, and 25.181 must be met with flaps and landing gear retracted. **Except as noted in FAR/JAR 25.253(c), it** may not be less than a speed midway between V_{MO}/M_{MO} and V_{DF}/M_{DF}, except that, for altitudes where Mach number is the limiting factor, M_{FC} need not exceed the Mach number at which effective speed warning occurs

(c) The maximum speed for stability characteristics with the ice accretions defined in Appendix C, at which the requirements of 25.143(g), 25.147(e), 25. 175(b)(1), 25.177 and 25.181 must be met, is the lower of 300 knots CAS or V_{FC} or any lower speed at which it is demonstrated that the airframe will be free of ice accretion.

<u>FAR/JAR 25.1419 Ice protection</u> – FAR 25.1419 is amended to adopt the conditional statement of JAR-25.1419 in the introductory conditional statement. Current FAR 25.1419 bases the need for showing an airplane can operate safely in the icing conditions of Appendix C on the presence of ice protection systems, the introductory phrase reading, "If certification with ice protection provisions is desired. . .." Current JAR-25.1419 bases the need for showing an airplane can operate safely in the icing conditions of Appendix C on the desire of the applicant to certificate the airplane for flight in icing conditions, the introductory phrase reading, "If certification for flight in icing conditions is desired. . .." The introductory paragraph of both FAR and JAR

25.1419 is also amended to remove redundant text from the second sentence that refers to the "continuous maximum and intermittent maximum conditions of appendix C," which is already specified in the first sentence.

The initial approach taken by the FTHWG was to remove the optional nature of airworthiness certification for flight in icing conditions that currently exists in both FAR 25 and JAR-25. The basis for that approach was that in today's operating environment, with an emphasis on flexibility and minimizing interruptions to scheduled service, it is almost inconceivable that a manufacturer would propose a transport category airplane that is not intended to operate in icing conditions. Though not objecting to this proposal or the logic behind it, industry representatives expressed concern for the effect it would have on the long-standing practice of issuing a Type Certificate, with a prohibition against flight in icing conditions, before the icing program was complete. This type of approval has been used to permit manufacturers to deliver airplanes to customers for non-revenue flying such as demonstrations, flight crew training, and familiarization – mandatory certification for flight in icing conditions would eliminate this flexibility. The favored option of the FTHWG was to grant this alleviation by adding appropriate text to the regulatory preamble; this approach was rejected by FAA legal counsel on the basis that the preamble material for a rule should not conflict with the regulatory content. A second option discussed by the FTHWG was to add a sub-paragraph to FAR/JAR 25.1419 that would explicitly state that the Type Certificate could be granted prior to completing the icing program provided the manufacturer submitted a plan for its completion prior to delivery of the first airplane or issuance of a standard Certificate of Airworthiness, whichever occurs later (similar to FAR/JAR 25.1529 requirements for Continued airworthiness); various iterations of this proposal were discussed in the FTHWG and, though legally acceptable, it was rejected due to subtle differences in the manner that the member civil aviation authorities define and grant operational approval. Consequently, this NPA/NPRM proposes to amend FAR 25.1419 only to replace the current conditional statement, "If certification with ice protection provisions is desired. . .," with the text used in JAR-25.1419; "If certification for flight in icing conditions is desired. . .." This change was made for two reasons: 1) A literal reading of the current FAR 25.1419 wording implies the applicant does not have to show the airplane can be safely operated in icing conditions unless an ice protection system is installed, and 2) the JAR-25.1419 text will retain the optional nature of certification for flight in icing conditions, which in turn will permit the type certification of airplanes before the icing program is complete with an appropriate limitation against flight in icing conditions.

FAR/JAR 25.1419 Ice protection

If certification for flight in icing conditions is desired, the airplane must be able to safely operate in the continuous maximum and intermittent maximum icing conditions of appendix C. **To establish this** –

(a) An analysis must be performed to establish that the ice protection for the various components of the airplane is adequate, taking into account the various airplane operational configurations; and

(b) To verify the ice protection analysis, to check for icing anomalies, and to demonstrate that the ice protection system and its components are effective, the airplane or its components must be flight tested in the various operational configurations, in measured natural atmospheric icing conditions and, as found necessary, by one or more of the following means:
(1) Laboratory dry air or simulated icing tests, or a combination of both, of the components or models of the components.
(2) Flight dry air tests of the ice protection system as a whole, or of its individual components.
(4) Flight tests of the airplane or its components in measured simulated icing conditions.

(c) Caution information, such as an amber caution light or equivalent, must be provided to alert the flightcrew when the anti-ice or de-ice system is not functioning normally.

(d) For turbine engine powered airplanes, the ice protection provisions of this section are considered to be applicable primarily to the airframe. For the powerplant installation, certain additional provisions of Subpart E of this part may be found applicable.

<u>FAR/JAR 25, Appendix C</u> – FAR/JAR 25, Appendix C is amended to: 1) Create two subsections, one to define the icing atmospheric conditions and another to define ice accretions, 2) Add a definition of the "takeoff" icing atmospheric conditions, and 3) Define the limiting conditions for determining the ice accretions appropriate to each phase of flight.

New proposed Part 1 of Appendix C contains the existing definitions of atmospheric icing conditions and adds a definition of the icing atmosphere to be used in determining ice accretions for the takeoff phase of flight. One of the early industry objections to adopting the JAA NPA 25F-219 material for the takeoff phase was the inappropriateness of assuming the current Appendix C icing atmosphere exists at ground level. This topic was the subject of considerable discussion, including consultation with FAA meteorologists who provided valuable information relative to determining the icing potential of clouds.

The FAA meteorologists attested that the maximum liquid water contents (LWC) prescribed for Appendix C Continuous Maximum Icing conditions (0.80 grams per cubic meter (g/m^3)) will only be found near the top of cloud layers that are greater than 4,000 feet deep with the freezing point near the top of the cloud layer. The FAA meteorologists also stated that the amount of water vapor that can be held without condensation in a given volume of space is independent of the altitude and depends only on the temperature of the gas (water vapor, air, etc.) in that space. This fact would permit a universal definition of a takeoff icing atmosphere that would be equally applicable to all of an airplane's approved takeoff field elevations.

For determining the takeoff ice shapes, changes in the LWC must be considered in the segment of the flight path from the takeoff surface to 1,500 feet above ground level (AGL), though the lowest cloud base is generally above 100 feet AGL. Theory and experiment have shown that the LWC is smallest (usually less than 0.10 g/m^3) at cloud base and generally increases with distance above cloud base. The ice accretion on an airplane would be due to the gradually increasing LWC and normally decreasing air temperature as the airplane climbs from the runway to 1,500 feet AGL. Although measured data at low altitudes AGL are sparse, the FAA Technical Center's database on inflight icing conditions contains data for 99th percentile LWC limits as low as 2,500 feet AGL. When scaled to 1,500 feet AGL, a maximum LWC value of 0.35 g/m^3 results.

The FAA meteorologists also provided a computation of the theoretical maximum "condensed" water content possible at 1,500 ft. AGL with a temperature of 0° C at the cloud base; the resulting $LWC_{theor.\ max.}$ was 0.71 g/m^3. Measurements have shown that the actual average LWC observed in stratiform clouds is usually no more than half the computed theoretical maximum LWC, which in this case renders the same 0.35 g/m^3. Another case that may be conducive to takeoff ice accretion is dense fog at runway level with an ambient temperature of 0°C or less. In the unlikely event that the fog was to extend from ground level to 1,500 feet AGL, the airplane would be exposed to an atmosphere with a uniform LWC of approximately 0.30 g/m^3.

Based on the information discussed above, the FTHWG proposes to define the takeoff maximum icing conditions atmosphere as having a constant LWC of 0.35 g/m^3, which will provide a conservative estimate of actual conditions. The two other necessary characteristics to describe the takeoff icing atmosphere are a water droplet mean effective diameter (MED) (more correctly referred to in current terminology as median-volumetric diameter (MVD))and an ambient temperature. An MED value of 20μ was determined to be appropriate to such low level icing conditions by both industry and FAA icing specialists.

Selection of the ambient temperature for takeoff icing was predicated on the results of icing computer code predictions that showed the effect of temperature to decrease significantly as the temperature itself decreased. The ambient temperature of the takeoff icing atmosphere was selected as –9°C, the point at which any further decrease in temperature had a negligible effect on the resulting ice accretion. The definition of the takeoff maximum icing conditions was added as paragraph (c) of Part 1. The new Appendix C definition of takeoff icing conditions also notes that the takeoff maximum icing conditions exist from ground level to 1,500 feet above the takeoff surface to coincide with the definition of the takeoff path of FAR/JAR 25.111.

New proposed Part 2(a) of Appendix C contains definitions of the ice accretions appropriate to each phase of flight, along with any limiting conditions (e.g., altitude limits for "Takeoff ice" accretion); further considerations for the development of artificial and natural ice accretions are contained in the advisory material associated with these proposed regulatory changes. Each Subpart B flight requirement that must be met in icing conditions specifies which of these ice accretion is to be used in showing compliance. In order to reduce the number of artificial ice accretions that must be manufactured, proposed Part 2 also permits the use of an ice accretion determined for one flight phase to be used in showing compliance with the flight requirements of another phase, provided the applicant can show it has a more critical effect on the flight parameter being evaluated. Ultimately, the entire spectrum of flight testing could be done with the "Holding ice" accretion if the applicant can show it is the most critical for every flight phase and is willing to accept the penalties that will arise in other flight phases (e.g., use of "Holding ice" in the takeoff phase will generally have a large effect on performance).

One FTHWG member did not consider the combination of the proposed regulatory changes and associated advisory material to provide a definitive enough description of the ice accretions to be considered, particularly with regard to the variables to be considered in determining the critical ice shape for a particular flight phase; that member's views are expressed in the following position paper:

Flight Test Harmonization Working Group - Flight In Icing Conditions

ALPA Minority Position: Ice Accretions

The addition of the clarifying statements, "and all flight conditions within the operational limits of the airplane" and "configuration changes" to the critical ice accretion requirement is intended to insure that the full range of possible accretion locations for atmospheric conditions defined by this appendix are considered. The primary parameter of concern is location of the ice accretion on the airfoil. The majority position is that "flight conditions (e.g. configuration, speed, angle of attack, and altitude)" will provide for the most critical accretion. The proposed change merely insures the objective stated by the majority is in fact achieved.

In NASA research accomplished following the 1994, ATR-72 accident at Roselawn, Indiana and discussed in the NTSB's report, the observation that decreasing AOA causes an increase in aft ice accretion limit on the upper surface of an airfoil is reported. Likewise, the fact that airflow separation on the negative pressure side (upper surface for a typical wing) is caused by ice accretions on the upper surface is discussed. Research performed by M. B. Bragg and others at the University of Illinois has demonstrated significant variation in the effects on airfoil aerodynamics of a simulated ice shape depending upon its location on the negative pressure side of the airfoil.

Differing airspeeds and high lift device configurations significantly change the angle of attack, and consequently the location of the stagnation point around which any ice accretion forms on an airfoil. For normal operation this should make no difference on surfaces that are protected by the icing system. But for unprotected surfaces, in the failure case and for ice which accumulates prior to normal system operation, changing the location of ice on the suction side of the airfoil may be significant. Procedural restrictions (i.e. no holding with flaps extended, speed or configuration restrictions in case of ice system failure, etc.) could be used to limit the configurations necessary to determine the most critical ice accretion. However the full range of possible accumulation locations must be considered.

The NTSB, in their report on the EMB 120 accident at Monroe, Michigan concluded that: "The icing certification process has been inadequate because it has not required manufacturers to demonstrate the airplane's flight handling and stall characteristics under a sufficiently realistic range of adverse accretion / flight handling conditions."(Finding #27) Adoption of this critical accretion requirement clarification is necessary to fully answer this adverse finding and improve safety.

Majority Disposition of ALPA Position on Ice Accretions

The rules and guidance material drafted by the flight test harmonization working group consider ice accretions for all phases of flight and all configurations of high lift devices. The rules require that the effects of the ice accretion during the phases of flight with high lift devices extended be accounted for. The advisory material specifically recommends that natural icing flight testing with high lift devices extended in the approach and landing conditions be conducted

The research referred to in the minority position determined the effect on lift and drag of a spoiler-like protuberance located at various chord locations of a two dimensional airfoil. These data do not support the minority position because no data were presented in the references to connect either the protuberance shape or locations with airplane flight conditions or icing conditions, either inside or outside of Appendix C.

There were no data showing the effect of the protuberance on an airfoil with high lift devices extended.

The effect of a protuberance on a two-dimensional airfoil is much larger than the effect of a similar protuberance on a complete airplane with high lift devices extended, and the effect of a protuberance diminishes with increasing airplane size.

The effect of ice accretions similar to the protuberances tested in the reference were also considered by the FTHWG when it discussed ice accreted in conditions outside of Appendix C. The majority of the FTHWG decided not to include these accretions because the only icing design envelope available is Appendix C, and also because of the IPHWG tasking.

New Part 2(b) of Appendix C addresses specific concerns related to determining the ice accretions appropriate to the takeoff phase. As noted in the discussion of the Subpart B takeoff proposals, the FTHWG assumed the candidate airplanes would be in compliance with operating rules that prohibit pilots from conducting takeoffs with any frost, snow or ice adhering to certain airplane surfaces or require the airplane to be operated in accordance with an approved ground de-icing/anti-icing program, resulting in the airplanes being free of frost, snow, and ice up to the point of lift-off. Part 2(b) also clarifies that no crew action to activate the ice protection system is assumed until the airplane is 400 feet above the takeoff surface; this is consistent with the existing requirement of FAR/JAR 25.111(c)(4) that limits the number of configuration changes requiring crew action before reaching 400 feet above the takeoff surface (i.e., end of the second segment).

New Part 2(c) of Appendix C defines an ice accretion prior to normal ice protection system operation that must be considered. Further guidance is provided to define this ice accretion in Appendix 1 of the associated advisory material. This ice accretion prior to normal ice protection system operation is necessary since transport category airplanes will be required to fly with some amount of ice accretion, even with a fully operational ice protection system; this is equally true for what are commonly referred to as *anti-ice* systems as it is for *de-ice* systems. The ice accretion prior to normal system operation is to be determined as an exposure to the continuous maximum icing conditions of Appendix C, Part 1, that includes: 1) the time for recognition, 2) a delay time appropriate to the means of ice detection, and 3) the time for the ice protection system to perform its intended function after manual or automatic activation. Considerable discussion was dedicated to defining the delay time appropriate to the various means of "visual" detection. The advisory material describes two methods of visual detection: 1) recognition that some prescribed amount of ice has accreted on a reference surface, and 2) recognition of the first sign of ice accretion on a reference surface. A delay time of 30 seconds exposure to continuous maximum icing conditions was agreed to by the majority of the FTHWG members for both of these cases (and for crew recognition of visible moisture and temperature conditions conducive to icing). One member disagreed with the use of a 30 second time delay for a visual means of ice detection that relied on the flightcrew to recognize the first indication of an ice accretion on a reference surface and submitted the following position paper:

Aviation Rulemaking Advisory Committee
Transport Airplane and Engines Issues Group

Flight Test Harmonization Working Group - Flight In Icing Conditions

ALPA Minority Position: Delay Ice

1) Conditions (a) (specified amount prior to activation) and (b) (activation at first indication) of Paragraph A1.2.3 of the associated advisory material are really the same situation with a smaller amount required for condition (b). There is no technical reason for the difference in 143 & 207 requirements for (a) and (b). Since checking outside the cockpit (not even close to a primary IMC visual scan pattern) in all visibility's and lighting conditions is required for both (a) & (b) they should have the same basic maneuver and stall protections.

2) The 30 second & 10 second times are now clearly pilot reaction times. I can accept a 10 seconds reaction time following indication from an ice detection system if the indication meets appropriate warning system criteria. As it stands now the indication could be a light on the overhead panel, which would clearly not be appropriate for a 10 second time. I believe this was discussed at either FTHWG #15 or #16; was its omission an oversight or is there perhaps an existing requirement for such indications?

3) I can accept the reduced maneuver and stall requirements for conditions (c) through (e), even though the 30 second reaction time is a stretch for me in condition (c) - we expect pilots to keep one eye on the TAT gauge whenever in visible moisture and react within 30 seconds to a change on a gauge that is not in anyone's primary scan. However, I can not accept 30 seconds for the pilot delay with indications outside the cockpit. I would reluctantly accept the 2 minutes as originally proposed because of the precedent in 33.77; although I am certain that any human factor study would produce a longer time between the specified accumulation and recognition by pilots. The problem is not in the time to react to an ice accretion after it is observed. The problem is insuring that no more than something around 20 seconds passes between checks of the representative surface. Many flights operate for extended periods without ice accumulations in conditions conducive to ice formation. Repeated "dry holes" discourage frequent rechecks. Cockpit workload during the more critical holding and approach phases of flight further decreases the chance that the specified amount of ice will always be visually acquired within 20 seconds. The 5/27/99 Canadian TSB report on the Air Canada RJ accident in Fredericton, clearly shows these workload issues.

In an email that was copied to many of you, one FTHWG industry member said, "If the height of ice is an important factor for drag increase, it is not the major factor for handling qualities." If so, the additional ice accreted during the more representative recognition time would not have a major effect. Thus, there is no reason not to require it. Additionally, as the chairman of the IPHWG briefed the TAEIG on June 30, a significant number of Ice Protection Harmonization Working Group (IPHWG) members feel our rule eliminates the need for the operational rule nearly finalized by the IPHWG. The IPHWG rule (driven by incident/accident data analysis) responds to the critical problem of operations with ice accumulations prior to system operation. The rule requires "in conditions conducive to airframe icing" either an active detection and warning system, or operation of the icing system while in holding or on approach independent of accumulation." In other words, the data shows that pilot detection of icing has proven inadequate to prevent icing incidents/accidents at higher angles of attack (during holding and approach).

Majority Disposition of ALPA Position on Delay Ice

1. The test requirements for conditions (a) (specified amount prior to activation) and (b) (activation at first indication) are different because it is assumed the flightcrew will recognize the existence of icing conditions and be vigilant in monitoring the reference surface for the first indication of ice accretion. Hence condition (b) would be expected to have a smaller amount of ice accretion and that accretion would exist for a shorter time period than that of condition (a). This is the logic used in prescribing the less stringent flight test requirements for condition (b).

2. Airworthiness authorities would apply appropriate criteria, as they do with other systems requiring pilot action, in determining the applicability of the prescribed 10 second delay time to the method of indication used by the ice detector system (this would be covered by the general requirement of FAR/JAR 25.1301(a) for installed equipment to "Be of a kind and design appropriate to its intended function.

3. The pertinent point of the third paragraph is whether 30 seconds is an acceptable delay time for visual means of ice detection requiring the pilot to look outside the cockpit. The 30 second time delay is just that and provides a reasonable time period for the pilot to activate the ice protection system – the ice accretion prior to normal ice protection system operation is determined as the amount of ice that will accrete during the "recognition" (or detection) time combined with the further ice accretion that will occur during the 30 second delay time plus the ice that will accrete in the time between activation of the ice protection system and the point at which it performs its intended function, all in the continuous maximum icing conditions of Appendix C, Part 1.

Appendix C to Part 25:

Part 1 - Atmospheric icing conditions

(a) ...

(b) ...

(c)Takeoff maximum icing. The maximum intensity of atmospheric icing conditions for takeoff (takeoff maximum icing) is defined by the cloud liquid water content of 0.35 g/m3,

the mean effective diameter of the cloud droplets of 20 micron, the ambient air temperature at ground level of -9 degrees C. The takeoff maximum icing conditions extend from ground level to a height of 1500 ft above the level of the takeoff surface.

Part 2 - Airframe ice accretions for showing compliance with subpart B

(a) Ice accretions - General

FAR/JAR 25.21(g) states that in the icing conditions of Appendix C the applicable requirements of Subpart B must be met (except as specified otherwise). The most critical ice accretion in terms of handling characteristics and/or performance for each flight phase must be determined, taking into consideration the atmospheric conditions of part 1 of this Appendix, and the flight conditions (e.g. configuration, speed, angle of attack, and altitude). The following ice accretions must be determined:

(1) "Take-off ice" is the most critical ice accretion on unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation, between liftoff and 400 ft above the takeoff surface, assuming accretion starts at liftoff in the Takeoff Maximum icing conditions of Part 1, paragraph (c) of this Appendix.

(2) "Final Take-off ice" is the most critical ice accretion on unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation, between 400 ft and 1500 ft above the take-off surface, assuming accretion starts at liftoff in the Takeoff Maximum icing conditions of Part 1, paragraph (c) of this Appendix.

(3) "En-route ice" is the critical ice accretion on the unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation, during the en-route phase. At the applicant's option, "Holding ice" may be used in showing compliance with requirements that specify "En-route ice".

(4) "Holding ice" is the critical ice accretion on the unprotected surfaces, and any ice accretion on the protected surfaces appropriate to normal ice protection system operation, during the holding flight phase.

(5) "Landing ice" is normally "holding ice" unless modified by ice protection system operation during the landing phase .

(6) "Sandpaper ice" is a thin, rough layer of ice.

In order to reduce the number of ice accretions to be considered when demonstrating compliance with the requirements of FAR/JAR 25.21(g):

- The more critical of "Take-off ice" and "Final Take-off ice" may be used throughout the take-off phase.

- **"Holding ice" may be used for the en-route, holding, approach, landing and go-around flight phases.**
- **"Holding ice" may also be used for the take-off phase provided it is shown to be more conservative than "Take-off ice" and "Final Take-off ice"**

The ice accretion that has the most adverse effect on handling characteristics may be used for performance tests provided any difference in performance is conservatively taken into account.

(b) Ice accretions for the take-off phase

For both unprotected and protected parts, the ice accretion may be determined by calculation, assuming the Takeoff Maximum icing conditions defined in Appendix C, and:

- **that airfoils, control surfaces and, if applicable, propellers are free from frost, snow, or ice at the start of the take-off, and -**
- **the ice accretion starts at liftoff,**
- **the critical ratio of thrust/power-to-weight,**
- **failure of the critical engine occurs at V_{EF}, and**
- **crew activation of the ice protection system in accordance with an AFM procedure, except that after commencement of the take-off roll no crew action to activate the ice protection system should be assumed to occur until the airplane is 400 ft above the take-off surface.**

(c) Ice accretion prior to normal system operation

The ice accretion prior to normal system operation is the ice accretion formed on the unprotected and normally protected surfaces prior to activation and effective operation of any ice protection system in continuous maximum atmospheric icing conditions.

Economic Impact

(To be added)

Proposed Advisory Material

(Referenced and provided under separate cover.)

Revision (03/01/00): Inserted § 25.107(g) to be consistent with 1g stall rule definition of V_{FTO}.
Existing § 25.107(g) became § 25.107(h).

Revised speed reference in § 25.121(c) from "at not less than 1.18 V_{SR}" to "at V_{FTO}" to be consistent with 1g stall rule.
Revised speed reference in § 25.123 from "1.18 V_{SR}" to "V_{FTO}" to be consistent with 1g stall rule.
Revised preamble material for § 25.207 discussing use of artificial stall warning for all configurations to better reflect regulatory wording.